CITY OF BOSTON

City Document No. 3.

THE SEWERAGE OF BOSTON.

A Report by a Commission consisting of E. S. Chesbrough, C. E., Moses Lane, C. E., and Charles F. Folsom, M. D.

To His Honor Samuel C. Cobb, *Mayor of Boston:* —

The Commission appointed in pursuance of the following orders, —

City of Boston, in Board of Aldermen, February 23, 1875.

Ordered: — That His Honor the Mayor be hereby authorized to appoint a commission of three civil engineers of experience in the subject, to report upon the present sewerage of the city; the discharge of sewers into Charles river, Stony brook, South bay, or Dorchester bay; the necessity of any high-water basin on the site of the present full basin, for flushing purposes; the expediency of relieving the sewers at the South End by pumping; and to present a plan for the outlets and main lines of sewers for the future wants of the city; and report, if it is expedient, in connection with the proposed works, to provide for any water basins, or marginal driveways, as ornamental and sanitary features of the city, the expenses to be paid from the appropriation for sewers.

City of Boston, in Board of Aldermen, March 1, 1875.

Ordered: — That the order passed by this board, February 23, 1875, authorizing the Mayor to appoint a commission to report upon the present sewerage of the city, be so far modified, in case His Honor the Mayor should deem it expedient, as to make the said commission consist of two civil engineers, and one competent person skilled in the subject of sanitary science, instead of three civil engineers, as provided in the order quoted above; and that the said commission shall, in addition to investigating and reporting upon the several subjects recited in the original order, report an approximate estimate of the expense of any plan, or plans, for a system of sewerage submitted by them —

has the honor to submit the following report: —

Introduction.

For many years past there has been a growing feeling among the more intelligent of our community, and particularly among physicians, whose habits of study lead

them especially to watch the public health, that our high death-rates * are connected more or less directly with the defects and evils of our sewerage-system, more especially in the low-lying and originally tidal districts, — evils which are increasing from year to year, and which have been and are so manifest to the senses that it is not necessary here to more than allude to their existence.

* The following table will give, at a glance, the death-rates from all causes, and the total numbers of deaths from some of the principal diseases for all the years since the new registration laws came into effect. In 1874, the rate, excluding Charlestown, West Roxbury, and Brighton, was 24.9. In 1872 and in 1873 the rate was 27.6, excluding small-pox. In 1861 no registrar's report was published.

YEARS.	Annual Death-rates per 1,000.	No. of Deaths from Typhoid Fever.	No. of Deaths from Scarlet Fever.	No. of Deaths from Diphtheria.	No. of Deaths From Cholera Infantum.	No. of Deaths from Small-pox.	No. of Deaths from Consumption.
1861	22.0	...	...	...	...	...	...
1862	22.4	85	236	46	236	13	795
1863	25.2	130	130	108	342	11	795
1864	27.0	107	225	118	268	113	859
1865	23.6	125	50	51	261	113	713
1866	22.4	93	60	52	266	0	846
1867	22.3	108	306	47	231	144	766
1868	24.0	120	266	67	488	17	868
1869	23.4	138	230	61	365	6	916
1870	24.3	168	205	61	524	32	990
1871	23.5	176	111	36	527	23	1,080
1872	30.5	229	258	28	692	738	1,161
1873	28.4	243	472	60	616	302	1,194
1874	23.6	202	269	62	679	2	1,333

The annual death-rate for the ten months to November 1st, 1875, in Boston has been 26.73 per 1,000. The absolute number of deaths in that time from the following-named diseases have been: —

Typhoid fever	180
Scarlet fever	398
Diphtheria	254
Cholera infantum	673
Small-pox	1
Consumption	1,150

The deaths from typhoid fever, cholera infantum, and consumption remain at about the same rates as last year, while the numbers from scarlet fever and diphtheria have been very much increased. The figures for cholera infantum and small-pox will represent very nearly the mortality for the year from those diseases, but the others will be much larger after the deaths for November and December shall have been added. From 1870 to 1875 inclusive the mortality from infantile cholera and consumption have been simply enormous, and there has been no decrease from year to year, although Boston has now the best sanitary care of all the American cities.

The subject has been referred to in no doubtful terms in every one of the reports of the State Board of Health.* In their Fifth Report, they say: "We regard this question of drainage for Boston and its immediate surroundings as of an importance which there is no danger of overstating;" also: "The death-rate" (in 1873) "of the City of Boston is so high as to make its discovery a matter of the deepest interest to every citizen." In the fourth report of the same board it was urged that a competent engineer be appointed to survey the metropolitan district and suggest "a comprehensive and harmonious" system of drainage and sewerage; and in their third report the State Board of Health urged, as one of the strongest reasons for the appointment of a City Board of Health for Boston, that they could take steps "to establish plans of drainage adequate for our whole territory and harmonious in all their parts,"—a promise which that board has fully justified, for, since their appointment in January, 1873, they have constantly urged the matter upon the attention of the authorities.

On the 14th of April, 1870, the consulting physicians of the City of Boston† addressed to the authorities a remonstrance as to the then existing sanitary condition of the city, in which they declared the urgent necessity of a better system of sewerage, stating that it would be "a work of time, of great cost, and the highest engineering skill."

Of such great importance has the matter been considered by our State Legislature that, in the special session of 1872, they passed an act‡ authorizing the appointment of a Commission, to be paid by the City of Boston, to investigate and report upon a comprehensive plan for a thorough system of drainage for the metropolitan district. This was not accepted, on the ground that the expense should be shared by the other cities, and no Commission was appointed.

In their fourth communication (December 28th, 1874) to the City Council upon the necessity of improved sewerage, the City Board of Health pointed out clearly the evils of our present system, and strongly urged that a radical change should be made, whereupon this Commission was appointed.

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* First Report, p. 56.
Second Report, pp. 14, 57, and 352.
Third Report, pp. 307 and 309.
Fourth Report, p. 6.
Fifth Report, p. 6.
Sixth Report, pp. 5, 6, and 334.

† Henry Bartlett, M. D.; George Derby, M. D.; James C. White, M. D.; William Read, M. D.; Paschal P. Ingalls, M. D.

‡ An act to provide for a Commission on the subject of drainage and water-supply for the City of Boston and vicinity [chap. 366].

The Board had daily evidence of the connection between decomposing matter from our sewers and disease, and the experience of the rest of the world confirmed that of Boston. London, Paris, Brussels, Hamburg, Dantzig, Frankfort-on-the-Main, and many other cities have had their sanitary condition so remarkably improved by better sewerage that Berlin, Stuttgart, Munich, St. Petersburg, and many others of the cities of Europe are fast following their examples.

In all these places, the cardinal principle is to get their sewage away, far out of reach, *before putrefaction begins.*

Striking as the experience of these cities has been, that of England has been equally so; and, as there are many fruitful lessons for us in it, the paper of Dr. George Buchanan is quoted at some length, although it has been often referred to here and in the various countries of Europe.*

* The accompanying table shows the most striking of the improvements which resulted from proper works of drainage, sewerage, and water supply.

NAME OF CITY OR TOWN.	Decrease (−) or Increase (+) per cent. of Annual Death-rate.	Decrease (−) or Increase (+) per cent. of Death-rate from Typhoid Fever.	Decrease (−) or Increase (+) per cent. of Death-rate from Pulmonary Consumption.	NAME OF CITY OR TOWN.	Decrease (−) or Increase (+) per cent. of Death-rate from all causes.	Decrease (−) or Increase (+) per cent. of Death-rate from Typhoid Fever.	Decrease (−) or Increase (+) per cent. of Death-rate from Pulmonary Consumption.
Bristol	−1½	−33	−22	Penzance	0	+6	−5
Leicester	−4½	−48	−32	Salisbury	−20	−75	−49
Merthyr	−18	−60	−11	Chelmsford . . .	+10	+5	0
Cheltenham . . .	−4½	−37	−26	Ely	−14	−56	−47
Cardiff	−32	−40	−17	Rugby	−2½	−10	−43
Croydon	−20	−63	−17	Penrith	0	−55	−5
Carlisle	−8	−2	+10	Stratford	−7	−67	−1
Macclesfield . . .	−20	−48	−31	Alnwick	−6	−36	+20
Newport	−32	−36	−32	Brynmaur . . .	−15	−56	+6
Dover	−7	−36	−20	Worthing . . .	0	+23	−36
Warwick	−7½	−52	−19	Morpeth	−6	−40	−8
Banbury	−12½	−48	−41	Ashby	−9	−56	+19

The death-rate among infants, and from measles, scarlet fever and whooping-cough, has been reduced very considerably, but in about the same proportion as the total from all causes. The decrease in the prevalence of typhoid fever has been very notable. The death-rate from consumption had decreased in a marked degree, and, generally speaking, *in proportion as drying of the soil had been accomplished by the sewers,* thereby confirming the conclusions of Dr. Bowditch of this city.

ORGANIZATION OF THE COMMISSION.

At the first meeting of the Commission, April 23, 1875, they were addressed by His Honor Mayor Cobb, who stated that the subject of the sewerage of Boston was the most important which he had been called upon to consider. He referred to our high mortality, and to the fact that it was considered by a large part of our citizens,* and especially by physicians, to be in a great measure due to causes connected with our sewerage.†

Chelmsford is the only town in the list in which the general death-rate had increased. This is explained by the facts that the outfall of the sewer was badly constructed, and that the outflow of the sewage was so far obstructed as to cause *backing up of the water into adjoining cellars and escape of the "mephitic vapors" into the streets and houses.*

The improvement would have appeared greater in Bristol, only a part of which had been well sewered, if it had been possible to calculate the death-rate for the precise area improved. In Penzance, the new sewers had just been completed, when the facts were collected.

In Rugby and Carlisle, where the improvement had not been great, there had been some *backing up of the sewage and some escape of the sewer gases into the houses;* and in Worthin, where the death-rate from typhoid fever had decidedly increased, *the sewage flooded certain basements, and the foul gases escaped into the air.* [Ninth Report of the Medical Officer of the Privy Council, London, 1867.]

The International Medical Congress at Vienna, in 1874, the German Public Health Association, and the Sanitary Association of the Lower Rhine, have unanimously confirmed the truth of Dr. Buchanan's conclusions, and are now urging them upon the cities of Germany.

* See Appendix B.

† The averages of the rates of mortality in Boston, since registration began, divided into periods of five years each, are as follows. For at least the first thirty years, the returns are quite inaccurate.

PERIODS OF FIVE YEARS.	DEATH-RATES.	PERIODS OF FIVE YEARS.	DEATH-RATES.
1811–1814 (4 years)	19.75	1845–1849	28.74
1815–1819	22.3	1850–1854	26.64
1820–1824	23.06	1855–1859	23.8
1825–1829	19.4	1860–1864	24.26
1830–1834	20.1	1865–1869	23.16
1835–1839	21.7	1870–1874	26.06
1840–1844	20.4		

Comparing the averages of the death-rates per 1,000 of the largest ten American cities for the past ten years, we have the following figures: —

New Orleans	35.45
New York	30.49
Brooklyn	25.40
Baltimore	25.19
Boston	24.66
Chicago	24.00
St. Louis	23.52
Cincinnati	22.40
Philadelphia	21.98
San Francisco	21.83

This system of sewerage for Boston, he said, should be adapted to the wants of a growing city, should be comprehensive enough to include the whole metropolitan district, and should be capable of extension without material altera-

There was no registration of deaths in Brooklyn, Cincinnati and San Francisco until 1866, and the returns of those cities are therefore computed for nine years. The rate of Chicago is very near that of Boston. In St. Louis and Cincinnati the returns for at least some of the years are very easily shown to be inaccurate. Philadelphia and San Francisco have much lower rates than Boston, and there is no reason to suppose that their statistics are far from the truth, as the following table shows: —

NAME OF CITY.	NUMBER OF DEATHS PER 10,000 IN 1874, FROM		
	Cholera Infantum.	Consumption.	All Lung Diseases.
San Francisco	6	25	40
Philadelphia	11	30	46
Boston	21	40	64
Baltimore	22	30	41
Chicago	34	16	31
New York	31	39	72

In view of the enormous infant mortality of Chicago, their general death-rate of 20.31 per 1,000, returned in 1874, looks suspiciously low. It can hardly be that their deaths were all registered, unless it be that the estimate of the population was too high.

London, which has reduced its rate of mortality from 42 to 22 per 1,000 between 1690 and 1872, and which still has many of the difficulties to contend with which do not exist in a new city like Boston, has a smaller death-rate, as will be seen by the following figures: —

Mean of 10 years, 1850–1859 . . . . . 23.6
" " " 1860–1869 . . . . . 24.6
" 5 " 1870–1874 . . . . . 23.02

It must be remembered that the average number of persons living on each acre of land in London is double that of Boston (including suburbs in both cases), and that fifteen-sixteenths of its water-supply, although filtered, comes from rivers, — that from the Thames being polluted by the sewage of four cities, — while the water-supply of Boston is probably not yet seriously contaminated by the sewage of Natick, although it might be difficult to say what the result would be in case of an outbreak of typhoid fever at that place.

The mortality was higher in London in the decade from 1860 to 1869, owing to the idleness and want and disease among the laboring classes caused by the "cotton famine" during our war.

In 1872, 1873 and 1874 the deaths per 1,000 in London were respectively 21.5, 22.5 and 22.5; while for the same years in Paris they were 21.9, 23.2, and 22.4. Pettenkofer, in commenting severely on the high death-rates in Germany in 1872, said that that of Munich should be reduced at least to 22 per 1,000, which certainly is not a high standard, and which had been more than attained in London in that year.

[Since the preparation of this note, there has been published the Report on the Sanitary Condition of Boston by a medical commission consisting of Drs. Charles E. Buckingham, Calvin Ellis, Richard M. Hodges, Samuel A. Green and Thomas B. Curtis. The whole subject has been treated in such a masterly and exhaustive manner that we refer to it for details that would not be in place here, contenting ourselves with a simple brief extract. They state "that the death-rate of Boston, *compared with her own past death-rates*, or with those of the *generality* of great cities, can hardly be called *excessive;* but that her sanitary condition is, nevertheless, only *fair*, inasmuch as a considerable proportion of mortality takes place which is due to remediable causes." The italics, except the last, are ours.]

tion in its plan; especially in view of the fact that there is every reason to believe that twenty years hence the city will contain a population of at least 900,000.

The Commission report the following results of their investigations, and the conclusions at which they have arrived.

The appointment of a Park Commission will make it unnecessary for us to discuss that question except in as far as it may be intimately connected with any proposed change in our sewers.

PRESENT CONDITION OF THE SEWERS.

While Boston was a city of about seven hundred acres, the lines of drainage were short, the grades were sharp, the sewage at its points of discharge was so much diluted in a vast volume of water as to render it practically innocuous, and the emanations from it were mixed with so many times their bulk of the purest air that they could not have contaminated our atmosphere to a serious extent.

The growth of the city in various directions, and the reclamation of land from the sea, however, have necessitated the extension of a plan which was suited to the wants of the time, as far as the knowledge of the principles of sewerage then known allowed it to be so, but which is entirely inadequate to our present needs.

The filling-in of the old mill pond necessitated the extension of the sewers of that district to discharge into the canal; and, upon closure of the canal, the sewers were intercepted by a main which now discharges on both sides of the city, very irregular in grade, and whose two outlets are materially higher than its central point at Haymarket square, thereby causing obstructions in that whole drainage area. No dispensary physician who has had that district can have failed to notice the deleterious influences of such conditions upon the health of people who are absolutely powerless to help themselves.

The South bay district contains so many old covered wharves and stone walls, and has been filled in with such bad material, that the tide actually ebbs and flows in some parts of it; and, although the drainage may be much improved by a different plan of sewerage, the soil there can never be such as to justify the use of the cellars as tenements.

When the sewage of Boston Neck was discharged at a low point in the closed basin, formed by the Mill Dam and the Cross Dam (now Parker street), the cellars were quite dry, although often put too deep. But when the odors from

this closed basin became so offensive as to necessitate its connection with the Charles river to keep it flushed and clean, the sewers had to be discharged on the south side of the city into the South bay; and the cellars were flooded during storms at high water, inasmuch as tide-gates were necessarily used to keep the sewers, and consequently many of the cellars, from inundation at every tide.* This rendered the raising of the Church-street and the Suffolk-street districts necessary, at the cost of several million dollars. Raising the area below Dover street made the cellars in this street still more subject to floodings than before, being the lower point; and when Dover street itself was raised Milford and Dwight streets beyond it suffered a similar increase of trouble.

Near Berlin street, and at several points on the southerly side of the city, the drainage is so imperfect, on account of the low grade, as to forbid the use of the land, as at present, for dwelling-houses.

The filling-in of the area below Charles street has removed the nuisance which existed there a few rods farther west, and it is to be regretted that better material had not been used in the process. A tight, impervious wall (like the Mill Dam) also should have been placed outside all the houses beyond Beacon and Charles streets, so as to prevent the soil from being soaked by each tide.

Finally, the Back bay proper has been filled in with the best of material, generally speaking, but at a grade and of an extent such as to make large tide-locked sewers at slight grades and of great length necessary.

In all, we have many hundred acres of this low, flat land, and just in proportion as we have extended such territory for residences, just so far have we been creating difficulties for ourselves which other cities are unfortunate enough to have had from the beginning, and which some of them have met and are meeting at great cost, and by the employment of the highest engineering skill.

THE SEWERS THEMSELVES.

In the limited time of eight months the Commission have not been able to examine in detail the whole of the one

* A great deal of the difficulty here is explained by the following extract from City Document No. 14, 1850, a report in respect to the drainage of the Back bay, by Messrs. Rogers, Chesbrough and Parrott: "As the law now stands, any proprietor of land may lay out streets at such level as he may deem to be for his immediate interest, without municipal interference; and when they have been covered with houses, and a large population are suffering the deplorable consequences of defective sewerage, the Board of Health is called upon to accept them, and assume the responsibility of applying a remedy" [p. 6].

hundred and sixty miles of sewers in Boston; nor would that properly come within the scope of a report upon a *system* of sewerage; but they have inspected the most important ones and over four hundred manholes.

The modern sewers in Boston are, most of them, well-constructed and of good material. Some have been built to meet immediate emergencies, and without the expectation of their being permanent. The city authorities, too, have not felt the expediency of expending sufficient money for a comprehensive system with each part in harmonious connection with the rest. There are now in the city proper thirty-two independent drainage-districts, the principal sewers of which were built in different years, often widely apart, discharging by separate outlets. This condition obtained in London until twenty years ago, and in most cities which had any sewers at all.

In most parts of the city there are enough manholes to allow of free inspection of the sewers. Directly underneath these manholes, with few exceptions, are "catch basins" in the course of the sewers, each containing and retaining a large amount of organic matter in a state of putrefaction. They cannot ever be properly cleaned, and must always of necessity be full of sewage; the annual or semi-annual clearing-out only serving to remove the sand and other solid matters. There are thus several hundred literal open-mouthed cesspools connected with the houses in all parts of the city. This plan was adopted in order to prevent the sewers, many of which were quite flat, from becoming obstructed by deposits. It has been tried on a small scale, too, in London, Paris, Liverpool and New York; but in all these cities it has been found a source of annoyance and danger to health, and has been abandoned. When the sewers in Boston shall have been accommodated to a system which will allow the sewage to be rapidly discharged, these catch-basins, which are unnecessary, should be filled; and earlier, if possible.

The street-gullies for the surface water are located by the Street Department, must be connected with the sewers by the Sewer Department, and are emptied from time to time by the Health Department (not the Board of Health), — a complication which entails many evils, and which should be done away with. They are trapped, and have catch-basins for collecting the street washings. They are often sources of very serious annoyance in two ways: —

1st. The water occasionally evaporates from the traps during the summer, exposing the contents to the air and

leaving direct communication between the sewers and the outer air.

2d. The same result is brought about during the process of emptying and cleaning them, as the traps are often left to be filled by the next rain.

Between Federal-street bridge and East Concord street there are five sewers with tide-gates, which are closed nearly one-half of the time. The area drained by them is comprised within the following limits: From the wharf of the Albany Railroad, following the line of their track to the junction, thence along the Providence Railroad as far as Northampton street, and through it to the corner of Tremont street, diagonally across to Concord street near its junction with Tremont street, and finally down East Concord street to the Roxbury canal, in all 445 acres. From this large tract come complaints of damp cellars, wet cellars, and, in case of heavy rain at high tide, of flooded cellars. The evils are greater or less as the grades of the streets vary from thirteen to eighteen feet above low-water mark, but in all cases reasonable causes of complaint.* In most cases the cellars are overflowed with surface-water, but "wooden plugs," or flap-traps, are liable to get out of order, and then a rush of sewage comes in and contaminates the air of the houses for months.

The Back bay and Church-street districts, three hundred and forty-one acres, drain into the Charles river by tide-locked sewers, which are large enough to serve as reservoirs for the greatest rainfall which has ever been known in Boston, even if occurring at high tide. The cellars are therefore not flooded unless they be built below the grade established by the city authorities (twelve feet above low water mark), or surface-water should get in from the yards or sidewalks. During nearly twelve hours of each day some or all of these sewers have no outlet, the sewage accumulates, rising higher and higher, leaving a slight deposit on the sides, and a very considerable deposit on the bottoms of the sewers. At the last time of inspection, this latter was, and nearly always is, in the Berkeley-street sewer, from four to six inches deep between Boylston and Marlborough streets, while the action of the tide keeps the part below Marlborough street comparatively clean. The evils in this sewer, which is selected as an example of a class, are twofold: first, there is always a large amount of the most offensive and deleterious gases present, which *can* pass under any

* See Appendix C.

circumstances through any water trap, to some extent. Secondly, the rapid rise of the sewage in the sewers, when they are closed by the tide, and especially if there be a heavy rain at the same time, compresses the gases to such an extent that they *must* force their way through the water traps,* provided there be not free ventilation, as there generally is not in Boston. The difficulty is especially great here, as the houses are of such various heights that it is difficult in most cases for one man to use his rain-water spouts as ventilators, without endangering the sleeping-rooms of his own or his neighbor's house.

The sewer in Boylston street, west of Park square, is so low, from settling of the land, that it cannot be emptied even at low tide; and there is a large quantity of offensive deposit in it; that is to say, it is, as is the Berkeley-street sewer, an elongated cesspool.

In one of the streets of Roxbury the house-drains are flooded, and offensive matters are brought into the houses by even such a rainfall as that in the early part of October last. The sewer, being closed by the tide, is of insufficient size to meet an extra demand upon it at high water.

The large sewer running through Canal and Haymarket streets, and having outlets on both sides of the city, was found last July to have a solid deposit five feet deep, so hard that it was difficult to thrust a pole through it. It cannot be cleaned satisfactorily, as it lies so low that workmen can enter it only at or near low tide. No systematic attempt, therefore, is made to clear it farther than to dam one end, or to dig holes through the deposit under the manholes, and thus allow a partial scouring to take place. It is one of the old square wooden sewers, and is also described as a type of a class.

Finally, between Otter street and Federal-street bridge, there are no tide-gates, many of the sewers lie very low, the soil is incompletely drained, the cellars are many of them often wet, and the sewer-gases are driven into the houses by the rise of the tide.

Considered with reference to their outlets, it is certainly a very serious objection, in a sanitary point of view, that twenty million gallons of sewage are discharged at forty

* The same evil would arise in case of an elevation in the temperature within the sewers, which frequently happens from the objectionable practice of letting waste-steam escape into them, and which may happen from the discharge of a large amount of hot water from any of the houses in that street. A violent wind, too, if blowing from the suitable direction, when the tide-gates are open, drives the sewer gases with great rapidity and force through the traps into the houses. Ventilating pipes, unless of the full size of the soil-pipes, are not protection against this last evil.

different points, completely skirting our city and polluting the atmosphere throughout most of its length and breadth.

In Cambridge, there are ten sewer-outlets into the Charles river above West Boston bridge, and four* below it. From Somerville and East Cambridge the enormous sewer from the Miller's river district discharges under Craigie's bridge, giving forth most offensive odors. In Charlestown there are twelve sewer-outlets, in East Boston thirteen, in South Boston eighteen, and in Somerville six. They are, with comparatively few exceptions, so situated as to discharge the contents of the sewers directly into the docks, or upon large surfaces of impervious dock mud.† Under the influence of the moisture and heat in summer, this highly putrescible organic matter gives forth such offensive gases as to render it impossible to remain with comfort in some of the most costly houses in the city.

During the past summer it has been necessary to close windows in various parts of the city to keep out the bad smells; and workmen in the vicinity of the Roxbury canal have not unfrequently been obliged to leave their work, while the atmosphere in the neighborhood of some of the worst places, as the flats near Porter street in East Boston, the Roxbury canal, the Stony-brook outlet, the Otter-street outlet, the channel below Prison Point, and Craigie's Bridge, has been simply intolerable.

Great as these evils are, they can only increase as the city grows and the population becomes more dense.‡

HOUSE-DRAINS, CESSPOOLS, ETC.

Without underrating the danger and discomforts arising from the present condition of our sewerage, it would be a great omission not to state that, in many cases, bad smells which have been attributed to the sewers really arise from defects in the arrangements belonging to the houses.

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* The three of these formerly discharging into Broad canal are emptied into a single main, to be carried out to deep water.

† The injury done to wharves, caused by deposits in the docks, has been in some cases not inconsiderable.

‡ The complaints were so loud in regard to the annoyance from Stony brook, that the Board of Health has been obliged to do something to afford at least a partial relief, if nothing more. Accordingly, by the advice of Mr. J. P. Davis, City Engineer, a temporary dam of loose stones has been placed at the outlet of the open basin, so as to retain enough water to keep the flats always covered, and yet allow as much ebb and flow of the tide as possible. The expedient is meant to last only a very short time, and, with that understanding, the general plan was cordially approved by the State Board of Health.

The City Board of Health has, also, in a great measure, abated the great nuisance from the discharge of the sewage of a part of Charlestown upon the flats near Prison Point.

In the first place come cesspools * and privies. In the sparsely-settled parts of the city they are in some cases unavoidable, and, if used for only a limited number of years, with proper precautions, need not be sources of nuisance or harm.

Privies should always be disinfected daily with a sufficient quantity of dry earth, and no drainage or soakage into the soil should be allowed from them.

Cesspools, at least in cities, should always be tightly cemented, and inspected by an official employed by the city, after each emptying, as is done in Paris. In such case they are not nuisances, if the contents are emptied by the pneumatic process, and removed to a sufficient distance. It is difficult, however, if not often impossible, to make cemented walls perfectly tight; and all such temporary arrangements should be abolished by law as fast as sewers are introduced. Nor is filling with earth sufficient, but it should be done with brick and cement, to prevent rat-holes, which are channels of communication for foul gases to the houses. How many of them still exist in Boston it is impossible to say, but they are to be found in some of our oldest streets. In high and dry gravel, sand, or loam, loose-walled cesspools may exist for years without harm, if there be no source of water-supply liable to contamination, and no cellars within their drainage areas; but they should always be looked upon with suspicion. Even under such circumstances, by the growth of a town, land may be needed for houses, which at one time had been thought to be so remote that it might be polluted with safety. The subsoil once saturated with cesspool-matter purifies itself slowly, and the cellar which is dug in it is not protected by the amount of care which the building of its walls and floors is likely to get.

In the house-drains themselves the most common faults are these: —

1st. That they are made of pervious or ill-jointed material, allowing contamination of soil, and afterwards of the air. They may, under some circumstances, pollute the water-supply, or defile the air distributed over the house by the furnace.

2d. That they are often made of lead pipe, which often becomes corroded, and finally perforated, thereby allowing the discharge of sewer gases. Dr. Fergus, of Glasgow, who has investigated this subject minutely, has known perforation to occur in lead pipes within three months after they had been laid.

* By this term is meant simply the cesspool, strictly speaking, a large receptacle for collecting all the refuse of houses.

3d. That they are often broken close to the house-walls, or even within the walls themselves, in the made land, from "settling," — a process which has been known to continue in Boston for at least a dozen years. This is an evil which is not usually detected early, often not until the sewage has soaked through the cellar-walls, and not unfrequently exists when not suspected by the occupants of the house.

4th. That they may be badly connected with the main sewer in the street, or broken at the same point by the settling of the land.

5th. That they often are laid under the floors of the cellars of the houses, thereby increasing the risk when any imperfections exist.

In the water-closets and wash-basins, trapping is often incomplete, and ventilation very deficient or entirely wanting.

Finally, wet cellars in Boston are often due to the settling of the land in the yards, whereby the surface-water sinks into the soil instead of running off by the drains.

The Made Land.

So much has been said in regard to the suitableness and unsuitableness of the "made land" for dwelling-houses, that the subject deserves especial mention.

The old Mill Pond, the South Cove, and large portions of the area between Dover and Northampton streets, have been filled with material more or less unsuited to the purpose,* and the evils of such a condition have been increased from the periodical floodings with water or sewage to which these places have been subject. In the first-named two districts the soil is spongelike in the readiness with which it allows water to percolate through it, rendering at least all the basements unfit for dwellings.

The Back bay proper, for the most part, has been filled in with excellent material, than which nothing could be better; and with proper precautions in building, no fear need generally be had of dangerous emanations from the deposits below it. This has been shown by experiments made during the past summer.† The level of the water in the soil, too, is especially uniform (an advantage in a sanitary point of view), and at such a level from the surface as to render the cellars dry,‡ unless built lower than is allowed by the city ordinances. Nevertheless the water is *too near the surface.*

* This is true also of part of the territory lying outside of Beacon street and Charles street.

† See Appendix D.

‡ See Appendix E.

The serious faults of the drainage here have already been pointed out and can be remedied.

In South Boston, East Boston, and Charlestown, there is so much high land and so little that is low, that the problem is comparatively a simple one.

In Cambridge, Somerville, and Chelsea, there is a large amount of low land that is not yet thoroughly drained.

Between Dorchester bay and Charles river we have a surface a thousand rods long, about half as deep at its widest part, and only six feet above extreme high tide. If this territory should be largely occupied by houses of an inferior class, thorough sewerage, at best a difficult matter, would be made even more so.

A reservation of land, therefore, especially with an open water-basin, as proposed by the late Governor Andrew,* could not fail to be of great benefit to the city, in a sanitary point of view.

The chief source of mischief in the made land is from the presence of sewer gases in and out of the houses (an evil which exists also to a greater or less extent in other parts of the city), and which may be ascribed to three causes.

First, to the immediate contiguity of large areas of moist surface, bare at low tide, and covered with an ever-renewing layer of sewage.

Second, to the bad character of the sewer gases, and to the fact that in manners already explained they must be constantly escaping, in greater or less quantity, a large part of the time, into some of our houses.†

Third, to the breaking of the house-drains caused by the land settling, while the houses built upon piles remain fixed. This is unquestionably a fruitful source of mischief, but it may be obviated by a very simple contrivance, namely, by leaving a small manhole for inspection close to the outside of the cellar-wall from the drain up to the surface of the ground. In this way any leakage would be readily detected, and the hole could be filled, in winter, with straw or some similar substance, to prevent freezing.

SUMMARY OF THE PRESENT CONDITION.

The evils which exist in our system of sewerage in Boston chiefly arise from additions being constantly made to the territory of the city, and from the sewers being necessarily extended through these low districts, and on very flat grades, without a definite comprehensive system.

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* Letter of March 10, 1860 [City Document No. 128, 1869, p. 102].

† It should be said here that the most deleterious of these gases are often not to be detected by the sense of smell, and that people, by becoming habituated to them, often are unable to detect what is noticeable to others, and which may be a source of danger.

The point which *must* be attended to, if we would get increased comforts and luxuries in our houses, without doing so at the cost of health and life, is to get our refuse out of the way far beyond any possibility of harm before it becomes dangerous from putrefaction. In the heat of summer this time should not exceed twelve hours. We fail to do this now in three ways: —

1st. We cannot get our refuse always from our house-drains to our sewers, because the latter may not only be full themselves at high tide, but they may even force the sewage up our drains into our houses.

2d. We do not empty our sewers promptly, because the tide or the tide-gates prevent it. In such case the sewage being stagnant, a precipitate falls to the bottom, which the slow and gradual emptying of the sewers, as the tide falls, does not produce scour enough to remove. This deposit remains with little change in some places for many months.*

3d. With our refuse, which is of an especially foul character, once at the outlets of the sewers, it is again delayed there to decompose and contaminate the air.

As a result of this failure to carry out the cardinal rule of sewerage, we are obliged to neglect the second rule, which is nearly as important, namely, ventilation of the sewers; for the gases are often so foul that we cannot allow them to escape without causing a nuisance; and we compromise the matter by closing all the vents that we can, with the certainty of poisoning the air of our houses.

Great as is the annoyance from allowing even the foulest sewage — emanations to escape into the open air, yet it is the safer way to do so, and has already been done in Boston in many cases by extending the soil-pipes through the roofs.

The sewage should start from the houses, and go in a continuous current without stopping until it reaches its destination, either in deep water or upon the land. In such case, the sewers will contain no offensive gases, and free ventilation may take place with a few simple precautions.

Remedies.

In the opinion of the Commission, there are only two ways open to us. The first, raising more than one-half of the superficial area of the city proper (excluding suburbs), is entirely out of the question, from the enormous outlay of money which would be required, — more than four times as much as would be needed for the plan which we propose,

* The catch-basins, too, in the course of the sewers, serve only to aggravate this evil, and should be filled as early as is practicable.

BOSTON MAIN DRAINAGE.

Plan shewing Main and Branch Intercepting Sewers recommended by the Sewerage Commission

1875

NOTE *The tinted portion of the Map shows the area included in the Corporate Limits of Boston.*

SCALE FOR PLAN

1 MILE 0 1 2 3 4 5 MILES

SCALE FOR PROFILE HORIZONTAL.

2000 Ft. 1000 Ft. 0 2 4 6 8 10000 Ft.

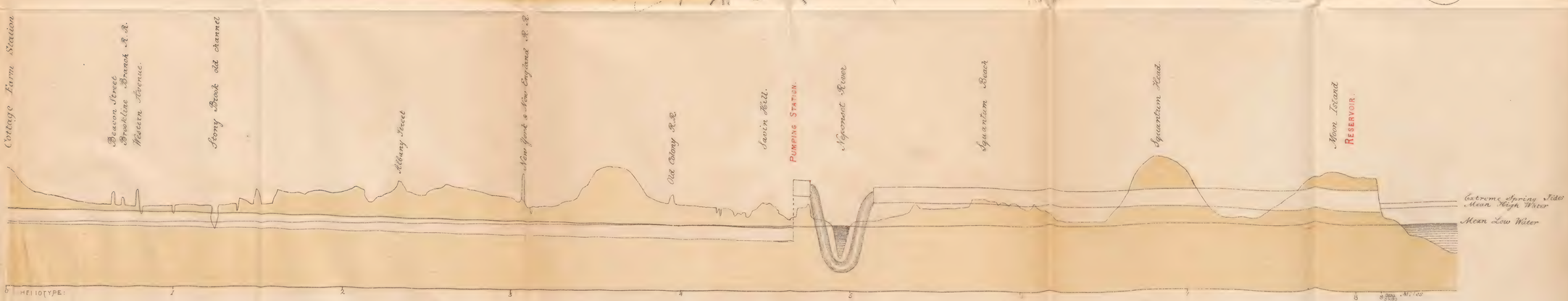
SCALE FOR PROFILE VERTICAL.

20 Ft. 10 Ft. 0 20 60 120 160 200 Feet

SCALE FOR SECTIONS

0 10 20 30 40 50 FEET

E. S. Chesbrough
Mons Lane
Chas. F. Folsom
} Commissioners



PROFILE OF SEWER FROM COTTAGE FARM STATION TO MOON ISLAND

and which consists in intercepting sewers and pumping. But before discussing these points in detail, we must decide what is to be done with the sewage, and where it is to be carried.

Final Disposal of the Sewage.

There are in use now in various parts of the world three methods of disposing of the sewage of large cities, where the water-carriage system is in use.

1st. Precipitation of the solid parts, with a view to utilizing them as manure, and to purifying the streams.

2d. Irrigation.

Neither of these processes has proved remunerative, and the former only *clarifies* the sewage *without purifying* it; but if the time comes, when, by the advance in our knowledge of agricultural chemistry, sewage can be profitably used as a fertilizer, or if it should now be deemed best to utilize it, in spite of a pecuniary loss, it is thought that the point to which we propose carrying it will be as suitable as any which can be found near enough to the city, and at the same time far enough away from it.

The third way is that adopted the world over by large cities near deep water, and consists in carrying the sewage out so far that its point of discharge will be remote from dwellings, and beyond the possibility of doing harm. It is the plan which your Commission recommend for Boston.* The work will require a large sum of money, but no larger than has been expended by other cities for the same purpose; only two-thirds as much as the city of Frankfort-on-the-Main has lately appropriated for their sewers, and a small sum when we consider the benefits which will come from it.†

Positions of Sewer Outlets.

In order to ascertain the best position for the outlet of a main intercepting sewer for that part of the metropolitan district south of Charles river, extensive experiments have been made during the past summer, with floats placed at six different points in the harbor. It has been very difficult to follow the courses of them all, for many successive days, as they became rapidly dispersed, and were often driven by wind and storm. A chart has been prepared, giving the courses of all these floats; but the multiplicity of lines would only confuse the reader, and therefore only the general results are given. They may be concisely stated as follows: —

Starting from Commercial Point, City Point, and Charles

* See Appendix F.
† See Appendix A.

river, below West Boston bridge, sewage would be deposited in large quantities even if discharged on the ebb tide, as it would return in considerable quantity by the next flood.

Starting from Castle island or Moon island, sewage discharged on the flood would be deposited, to a considerable degree, on the flats of the Charles and Mystic rivers, or on Dorchester and Quincy bay flats. Discharged at and immediately after high tide, it would generally go as far as Bell Buoy or Boston Light, with a certainty of not being a source of nuisance by the returning tide.

Of the two points just mentioned, Castle island is objectionable, for three reasons: —

1st. It is not remote enough from what will be soon a densely populated part of the city.

2d. The discharge of such a mass of sewage into such a thoroughfare as the main ship-channel should be avoided, provided another available point could be chosen.

3d. It can hardly be expected that sufficient land could be obtained from the United States government for the erection of the necessary works on Castle island, if, indeed, permission could be got to use the island at all. In South Boston sufficient land for a reservoir and pumps would be got only at great cost.

If the sewage were discharged into the channel of Dorchester bay, probably no offence would arise for some years; but the time would almost certainly come when the accumulation of organic matter would become so great as to render complaints quite frequent; for much of the sewage would pass backward and forward without getting farther than Spectacle island; and no inconsiderable quantity would be likely to deposit on the flats.*

For the cities lying north of Charles river the problem is more simple. The experience of the English cities Weymouth and Hastings leads us to conclude that sewage cannot be discharged on an ocean-beach without its being the source of a nuisance. With us the only available point where sewage would be carried from the northern outlet out to sea, by a rapid current, is Shirley gut.

The Intercepting System.

The plan recommended is to discharge all the sewage from that part of Boston situated between the Charles and Neponset rivers at the north end of Moon island.

The main intercepting sewer is to be located in nearly a direct line from Cottage Farm station to the Neponset river,

* See Appendix G.

near Savin hill, to cross this river by a siphon, and thence to be built along Squantum beach and across Squantum point to the end of Moon island.

The general course of this sewer will be understood from the following list of streets through which it is to pass, viz.: Beacon street from Cottage Farm station to St. Mary street; thence to the junction of Tremont and Cunard streets; thence in Windsor, Madison, Hunneman, and Yeoman streets and Norfolk avenue and Clapp and Mt. Vernon streets to Dorchester avenue; thence in nearly a direct line to Neponset river north of Savin hill. The sewage is here to be raised by pumping, and passes by a siphon under Neponset river into the main outlet-sewer.

The grade of the sewer at Cottage Farm station is to be one foot below low tide. The fall, or inclination, is to be one in twenty-five hundred, or twenty-five inches per mile. The sewer is to be circular, nine feet in diameter from Cottage Farm station to Albany street; nine feet by eleven (equal to a circle ten feet in diameter) thence to the pumping station; thence to the outlet at Moon island, at first ten feet by twelve (equal to a circle of eleven feet in diameter), and finally twelve feet by thirteen; thus enlarging the storage capacity of the outfall sewer.

The siphon under Neponset river is to be six feet in diameter and fifteen hundred feet long. It is designed to be of wrought iron, properly protected from the action of salt water. Chambers are to be built at each end of it for connecting a second siphon. The results of further surveys and borings at this point may show that it would make a more permanent and less expensive structure to build a brick tunnel laid in Portland cement with iron ribs to strengthen the masonry.

There is to be built at the outlet on Moon island a reservoir to hold twenty-five million gallons, which is somewhat more than the usual amount of sewage now discharged in twenty-four hours. The discharge into the sea is to take place at each tide for the first two or three hours after high water.

It is proposed to erect at the pumping-station three engines, of 145 horse-power each. This is a very liberal provision for the present; but, in view of the free use of water after the completion of the Sudbury aqueduct, it is thought best to make it. The lift will be from twenty to thirty-three feet. The grade of the outfall sewer is at this point fourteen feet, and at the outlet eight feet above low water.

The sewer from Cottage Farm station to the Neponset

river is to drain all that part of the city which lies between it and the Charles river and the harbor on the north; also all that part of the city south of it and at the same time below grade forty. It will be large enough to drain twenty square miles, and to take the sewage from a population of 750,000. Its capacity is three hundred and forty-five cubic feet per second, or over two hundred and twenty million gallons per day.

The size of the outfall-sewer is sufficient to carry the sewage from a population of one million, and also one-fourth of an inch rain-fall per day from an area of thirty square miles. Its capacity is four hundred and forty-five cubic feet per second, or over two hundred and eighty million gallons per day.

In determining the sizes of the sewers, we have assumed the amount of sewage to be seventy-five gallons per day per inhabitant; but, as the *maximum* flow would be at the same rate as if this were all to be discharged in *twelve* hours, we have fixed the sizes large enough to discharge double that amount, and, in addition to the above, an amount of storm water at the time of the maximum flow of the sewage equal to one-fourth of an inch of rain-fall per twenty-four hours. The large capacity of the sewers fixed upon will be sufficient to carry off or impound for the time a still greater rain-fall per hour. It should, however, be here stated that this plan contemplates the construction of storm-overflows at suitable points, so as to prevent in times of very great or long continued rains a surcharging of the sewers.

It is also to be understood that the natural water-courses in Dorchester, Roxbury, Brookline and Brighton, particularly Stony brook and Muddy brook, are to be kept open, and free and clear from sewage contamination, and that their channels are to be straightened and to discharge as at present into the Charles river; for no sewers could be built at reasonable cost large enough to carry off these waters in case of storms. If by the growth of the city it should ever become necessary to cover them or other natural water-courses, great care should be taken that their character as drains for the soil be maintained without allowing any ordinary sewage to be discharged into them, but only occasionally an excess of storm-water.

The sewage from those portions of the city situated south of the main intercepting sewer, and above the plane of forty feet above low water, can be intercepted by a high-level sewer and delivered into the outfall-sewer without pumping. The district is not now so densely populated as to require this; and for the next ten or fifteen years the sewage from

such portions as require sewers can be delivered into the low-level sewer and pumped.

The principal branch of the main sewer is to be located in Albany street, from Yeoman street to Kneeland street, and at this point to receive a lateral to be built in Kneeland, Federal and Broad streets, and Atlantic avenue to Central wharf; from the junction of Albany and Kneeland streets it is to be built in Kneeland, Elliot and Pleasant to Boylston, and thence to junction of Arlington and Marlborough streets and in Marlborough to Parker street. At the junction of Marlborough and Arlington streets it is to receive a branch to be located in Arlington, Beacon, Brimmer, Pinckney and Charles streets to Leverett street.

The location of this branch intercepting sewer on Marlborough street is recommended on account of economy in construction, and the saving of much annoyance to the public by obstructing Beacon street for so long a time as would be necessary, to say nothing of the danger of accidents to the water-mains there.

The desirableness, however, of keeping the tide more perfectly out of this district, the ground-water of which fluctuates in consequence of it from one to three feet at every tide, and any future examinations and negotiations which may be made with the owners of the property on the north side of the mill-dam, may satisfy the city that it would be better to rebuild the sea-wall there, making it water-tight, and then construct the sewer inside of it.

It is recommended to close that portion of the Roxbury canal west of Albany street. If this is done, the expense of a siphon for the sewer in Albany street will be saved; and the value of the land reclaimed will more than compensate for the expense of filling it, beside greatly improving the sanitary condition of this immediate vicinity.

The sewage from South Boston is to be intercepted by a sewer to be built in Dorchester avenue, A street, and First street to Second street. It is thought that for the present it will not be necessary to build this sewer farther than from its junction with the main in Dorchester avenue to B street, where it will intercept a large sewer, which now discharges into the South bay.

The sizes of the branch intercepting sewers will vary from four feet in diameter up to seven and one-half feet; their minimum inclinations are to be one in two thousand, or thirty-two inches per mile.

The inclination of all the sewers is to be sufficient to give a minimum velocity of about two miles per hour, and thus prevent any deposit of sediment in them.

It will be perceived by an examination of the most recent experience in connection with the sewers of European cities that more and more attention is paid to flushing them, notwithstanding they may have sufficient grades to be what is called self-cleansing. The advantages of this will be perceived when it is remembered that, in continued dry weather, the effective scour of a small amount of sewage may be considerably less than the average estimated for, and yet even the maximum must be provided for in the sizes of the sewers. With such experience before us, we would take advantage of the excellent facilities that exist for flushing purposes at high water, along the Charles river and other tidal fronts of the city, and from any tidal basin that may be constructed in the proposed park near the mouths of Stony and Muddy brooks.

We propose that the main and branch intercepting sewers shall be so constructed that no water will leak into them through their bottoms or side walls; for by just the quantity that may be thus allowed to leak into them will their efficiency be diminished. We also propose so to graduate the inlets of the lateral sewers into the main and branch intercepting sewers, that no more than the sewage proper and the due proportion of storm-water shall be allowed to enter; otherwise the storm-water would interfere with the proper action of the main and outfall-sewers. The details for effecting this, though simple in themselves, are, like others, necessarily omitted from this general report. The length of the main intercepting sewer and branches for the south side is fourteen and one-fifth miles.

The total estimated cost of the sewers herein recommended for the south side of the Charles river, including an allowance of three hundred thousand dollars for rebuilding old sewers and connecting them with the intercepting sewers, is $3,746,500, of which the details are as follows: —

Main Sewer and Branches to the Pumping-Station,	$1,483,182
Engines and Pumping-Station	300,000
Main Outfall-Sewer	875,000
Reservoir	350,000
Land Damages	125,000
	$3,133,182
Engineering and Superintendence, etc., 10 per ct.	313,318
	$3,446,500
Rebuilding and connecting old sewers . .	300,000
Total	$3,746,500

The main intercepting sewer for the district north of the Charles river is to commence in Cambridge at the north end of the approach to the Brookline bridge; its general course is through Waverly street to the Boston and Albany Branch Railroad; thence along the northerly side of the railroad, crossing Main street into Portland street, and in Portland, Medford, Poplar, and Redmond streets to Charlestown; thence in Cambridge and Alford streets to the Mystic river, crossing it by a siphon south of the Malden bridge to Bow street; thence across the marsh to Locust street south of the Eastern Railroad; thence through Chelsea parallel to the railroad to Chester street, and in Chester street to Marginal street; thence crossing Chelsea creek by a siphon to Breed's island; and across this island along the northerly foot of Breed's hill; and finally by a siphon across the inlet to Winthrop, and thence crossing Beach street near Main street, and passing west of Winthrop Head to the outlet at Point Shirley.

The grade of this sewer at the junction of Brookline and Waverly streets is to be two feet above low tide. The fall per mile is to be twenty-five inches. It is to be four and one-half feet in diameter to Main street, six feet in diameter to Cambridge street, and seven feet in diameter to the junction of Cambridge and Canal streets in Charlestown, where it receives the lateral sewer from that district. From this point to the west end of Breed's island, where the pumping-works are to be located, it is to be eight feet in diameter. The branch from East Boston is to join the main sewer at this point. From the pumping-works to the outfall at Point Shirley, the main sewer is to be nine feet in diameter. The capacity of this main outfall-sewer is two hundred and sixty-one cubic feet per second, or about one hundred and sixty-nine million gallons per day.

The principal lateral is to commence at the junction of Main and Third streets in Cambridge, and to pass through Third, Spring, First, Cambridge, Bridge and Prison Point streets to the mouth of Miller's river, crossing it by a siphon to Charlestown, and thence through First and Canal streets to the junction with the main line in Cambridge street.

This sewer is to be four and one-half feet in diameter from Main street to Charlestown, and thence to its junction with the main intercepting sewer five feet in diameter.

If the streets in East Cambridge should be filled out to the Commissioner's line, it would be better to build this sewer in Prison Point street, and in First street to the West Boston bridge.

For draining East Boston it is proposed to construct a

branch intercepting sewer parallel with and east of the Eastern Railroad, thence along Reynolds street to the creek, thence across Breed's island and around the westerly end of Breed's hill to the main north outfall sewer.

This sewer from Maverick street to Neptune street is to be four and one-half feet in diameter, and thence to the junction with the main sewer on Breed's island five feet in diameter For temporary purposes until the system of main intercepting sewers shall be built and in operation, Mr. Bradley's plan, which he has already commenced carrying out, is recommended; that is, to collect the sewage of the easterly side or slope into one sewer and discharge it into deep water at the southwesterly end of the island. The outlets of the other East Boston sewers do not cause any serious complaint at present.

It is proposed to erect at the pumping-station on Breed's island two engines of 145 horse-power each. The lift will be from twenty-three to thirty feet. The grade of the outfall-sewer is at this point seventeen and one-half feet above low water.

There is to be at the outlet near Point Shirley a reservoir to hold twenty million gallons, from which the discharge is to take place twice each day for the first two or three hours after high water.

The length of the main sewer and branches for the district north of Charles river is fifteen miles. Their estimated cost, including reservoir and pumping-station, and an allowance of one hundred thousand dollars for rebuilding and connecting old sewers with the intercepting sewers, is $2,804,564; of which the details are as follows: —

Main Sewer from Brookline bridge to Point Shirley, $10\frac{69}{100}$ miles	$1,538,395 00
Branch Sewers $4\frac{31}{100}$ miles	270,300 00
Engines and Pumping-Station	200,000 00
Reservoir	300,000 00
	$2,308,695 00
Land Damages.	150,000 00
	$2,458,695 00
Engineering and Superintendence 10 per cent.	245,869 00
	$2,704,564 00
Add for rebuilding old sewers, etc.	100,000 00
Total	$2,804,564 00

CONCLUSION.

It would not be practicable to enlarge the outfall-sewers in case future necessity should demand increase in that direction. Therefore a very considerable outlay must be made now to avoid such necessity; but it is not advisable to make the reservoirs much larger than the present population requires. Thus not only an important amount of interest may be saved, but considerable and valuable experience gained in the mean time both as to the necessity of future enlargements and the possible utilization of some of the sewage. We would, however, recommend the securing at once of all the land ever likely to be needed for reservoirs.

The surveys upon which this report is based were made under the direction of Mr. Wm. H. Bradley, C. E., Superintendent of Sewers, by Col. C. W. Folsom, C. E. We take pleasure here in acknowledging the courteous manner in which Mr. Bradley furnished all the information we asked, and the valuable suggestions made by him, which his long familiarity and experience with the peculiarities of Boston sewerage enabled him to do.

Among the many advantages of the general plan here recommended, viz., pumping the sewage and discharging the same at high tide, may be mentioned the following: —

1st. The sewage is removed entirely from the limits of the city and discharged so as to be carried out to sea, whence it will not return. Our experiments convince us that this can be done certainly on the ebb tide.

2d. *There is a constant and uninterrupted flow of the sewage from the time it enters the sewers until it reaches the outfall-sewer. All sewage is thus removed before it becomes offensive, and there is no deposit in the bottoms of the sewers.*

3d. In a system of sewers of this design skilfully constructed, the level of the ground water will be kept several feet lower than it now is. This point is one of great importance in view of the direct connection, as shown by Dr. Bowditch and Dr. Buchanan, between soil-moisture and pulmonary consumption, a disease which causes about one-sixth of the total number of deaths in Boston.

4th. It will be practicable to rebuild such sewers as have been extended from time to time on newly made ground, which consequently have little or no grade, sometimes with inclinations the wrong way, and which it is now very difficult, if not impossible, to keep clean.

No system of sewerage and no degree of perfection in the sewers themselves can be expected to render our dwellings

free from bad smells or danger to health unless the house-drains, soil-pipes, etc., be also carefully attended to.

We therefore recommend

1st. That soil-pipes be carried through the roofs to a point two feet above them, and not near chimneys or windows; and that they have on their tops some approved automatic ventilator, one of the best of which is Capt. Liernur's modification of Saint Martin's, originally proposed to the French Academy in 1788. Ventilating pipes may pass into chimneys if the latter are always kept hot.

2d. That rain-water spouts be untrapped and discharge into the sewers, *provided that their upper ends be remote from windows or the tops of chimneys communicating with rooms occupied by human beings.*

3d. That house-drains be made free from the faults mentioned on a previous page.

4th. That there be inspectors appointed, whose sole business it shall be to see that house-drains are properly constructed and kept in order.

5th. That no new houses be occupied until they have been properly inspected, and their drains have been found satisfactory.

6th. That an intercepting sewer, with branches and pumping-stations, be constructed according to the plans already given, the necessary modifications of the old sewers to be determined as the work proceeds.

7th. That the means recommended for flushing be freely used, and the sewers be kept as clean as possible.

8th. That the new sewers, and also many of the older ones, as they become clean, be ventilated by free openings, the positions of which are to be regulated by experience.

Finally, we have omitted many details, and we have avoided mention of many subjects which may perhaps be thought deserving of discussion; but we have been anxious to confine our report within reasonable limits, by avoiding perplexing minutiæ, and by touching only lightly upon matters of sanitary interest, which we have not space to discuss in full.

Respectfully submitted,

E. S. CHESBROUGH.
MOSES LANE.
CHAS. F. FOLSOM.

APPENDIX.

APPENDIX A.

Sewerage–Systems of Large Cities.

London. — When water-closets were first introduced in this city, about the beginning of the present century, they were connected with the sewers. The latter were large and badly constructed; and the pollution of the soil became so great that a law was passed forbidding their use as a means of discharge for the water-closets or privies. Cesspools were then built all over the city, and the nuisance so increased that another law was passed, in 1847, requiring that they should be abolished, and that connections should in all cases be made with the sewers.

The contamination of the soil from these various sources became so great, that in 1866, during the cholera epidemic, posters were placed upon all the city pumps, stating that the water was none of it fit for drinking purposes. Even at the present day cases of illness are not unfrequently traced to buried and forgotten cesspools, and many polluted wells are still in use.

In 1856 the stench from the discharge of sewage into the Thames had become intolerable; there had been two recent epidemics of cholera in the city (in 1849 and 1854), and the many evils in the sewerage system had become so great, that engineers and physicians had united in declaring the necessity of a change. As a consequence, the main-drainage scheme was adopted, consisting of five sets of intercepting sewers, with four pumping-stations.

The two outlets for the northern and southern sections of the metropolis are at Barking and at Crossness, respectively ten and fourteen miles below the city proper; and they are covered by the water at the time of discharge. At each outlet there is a reservoir capable of containing the ordinary sewage of twenty-four hours, if necessary. The discharge into the river from these reservoirs takes place only during the two hours succeeding high water, so that an abundance of time is given for the ebb-tide to carry all the sewage to a safe distance.

In the City of London proper, where the land is quite high, the sewers are well flushed, and they are ventilated by gratings placed at intervals, from one hundred feet to fifty yards apart, opening directly into the streets. Where the sewer-gases are especially foul, they pass first through charcoal filters. Ventilation is also got in the different parishes by extending the soil-pipes through the roofs, by special pipes carried up above the tops of the houses, and in some cases by connecting rain-water spouts with the sewers without traps.

The sewers of the main-drainage scheme are self-flushing, and are a perfect success; and the pumps work admirably, so that places so low that they must be protected from the Thames by embankments are thoroughly drained.

Many of the old sewers, however, especially where the sand and dirt from the streets are discharged directly into them, require cleaning from time to time. This is done by contract, and inspections are made every three months by the Sewer Department to see that it is properly done. They are also flushed by gates which hold the water back until the sewers are nearly full, and then, being suddenly opened, let it go with a rush.

Since the intercepting sewers were built, the level of the ground-water has been very much lowered, cellars formerly wet have become dry, and, in some few places, trees are even dying from loss of moisture in the soil.

The storm-water is discharged into the Thames by overflows, some of which are so low that they are tide-locked at high water. Consequently, in case of very heavy rain at high tide, which indeed does not often happen, those cellars which are placed below the grade established by the city authorities are liable to be flooded. This difficulty, however, has been obviated for a great part of the city by means of a sewer for surface water only.

All the attempts to utilize the sewage of London have proved failures from a pecuniary point of view. There is no nuisance to the metropolis created by the discharge into the river, and the surveys of the Board of Works convince them that the harbor is not filling up at all from sewer deposits. In fact, Sir Joseph W. Bazalgelte has given an opinion that the sewage actually helps scour the channel. All of the sewage of London goes into the Thames except that corresponding to a population of 20,000, which is utilized, at some pecuniary loss, on an experimental sewage-farm at Barking.

Liverpool. — The drainage of this city is a comparatively simple matter. Most of the land is quite high, and there are only 5,210 acres. The sewers are, generally speaking, excellent. There are nine main branches, each having a separate drainage-area, discharging into the Mersey at deep water, — in one case by a siphon, — and at points eight feet below high-water mark.*

In the low part of the city there are nearly three hundred acres occupied chiefly by warehouses and drained by tide-locked sewers; and, in case of heavy rain at high water, the damage done in the cellars of this district has sometimes been very great.

At the summits of the new branch-sewers, reservoirs are made of about five hundred cubic feet capacity, to be used for flushing purposes. In many cases, too, similar reservoirs are making for the old sewers, so that there will be finally several hundred of them; and they will be used as often as frequent inspection shows flushing to be necessary. It is thought that some of them will never be needed.

The plans of all new sewers and of all alterations in the old ones

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* The tide, as in London, rises and falls about twenty feet.

must be submitted to and approved by the Health Committee before they can be carried out.

In the lower parts of the city nearly three thousand pipes have been carried from the sewers through the roofs of the houses, to be used exclusively for ventilation. There have been complaints of bad odors from them in only two or three instances, in which cases they have been removed. Charcoal filters were used, too, at one time at the upper ends of the pipes, but were soon abandoned, as they were found to obstruct the passage of the sewer-gases.

In the better parts of the city, soil-pipes are carried up through the roofs, and rain-water spouts are used as ventilators in many cases where their upper ends are remote from chimneys and windows. The Sewer Department is also constructing ventilating shafts alongside of the manholes, and opening directly into the streets. The street-gullies are trapped, and are flushed in the summer time, so that they never shall become dry.

A few years ago the sewage was carried to a point north of the city and delivered by pumps upon a farm for irrigation; but the whole process was found so costly that it had to be abandoned. There is very little offence from the sewer-outlets, and a commission of engineers has decided that the bed of the river is not obstructed by the deposits from the sewage.

Leeds, a city of 300,000 inhabitants, has sewers for two-thirds of its population. In 1871 they were served with an injunction obliging them to cease extending their sewerage-system any farther until they purified the sewage before discharging it into the river Aire. They have tried the various precipitating processes, and are now using the A. B. C. in a modified form. The cost of their precipitating works has been £90,000, and their yearly expenses for working them amount to £15,000. The sewers are freely ventilated by untrapped street-gullies.

Manchester, a city of 4,516 acres, with a population of 356,000, has water-closets for only about 50,000. For the remaining 300,000, ash-closets, privies and cesspools are used, but the latter are fast disappearing. The ash-closets are emptied daily by carts, at a cost four times as great as that of the water-carriage system, and in a manner which is certainly much less inoffensive. The idea of the authorities is that the river Irwell will thus be saved from pollution; but it is already so fouled by manufactories that it would be difficult to say whether the slop-water and street-drainage do not pollute it so much that the additional discharge from the water-closets would make any difference or not. The better classes — only a few of whom live in the city itself — insist upon having water-closets in their own houses.

Birmingham has an admirable system of sewers, having water-closets connected with about two-thirds of the houses. At the present time they depend chiefly upon one of the precipitating processes to *clarify* their sewage; but, owing to its great expense and its failure to *purify* the sewage, they are trying to secure sufficient land for irrigation. The cost of the works is 13,000 pounds a year, beside the interest on the money invested. The return from the manure sold is trifling.

Bristol. — A long intercepting sewer has been built with its outlet four miles below the city.

Glasgow. — Water-closets are used in the better parts of the city, and elsewhere ordinary privies or charcoal-closets. The sewage of the city is discharged into the Clyde, which has been for nearly twenty years so fouled that people have avoided going up the river in steamboats during the summer. The sewers are not well ventilated, so that the gases ascend to the highest points, where also the best houses are, and are thought to give rise to a certain number of cases of typhoid fever. Typhus is common in the lower districts, where there are no water-closets. In 1868, Messrs. Bateman and Bazalgette, in their report, proposed a main-drainage system to carry the sewage out to sea many miles south of the mouth of the Clyde. Sir John Hankshaw has recently been asked to make a report on the question, and it is not yet decided what is to be done.

Edinburgh has not yet completed sewers for all of the lowest parts of the city, but is contemplating doing so. The sewage of the northern part of the city, which formerly created a great nuisance by its discharge into the river Leith, has been intercepted by a main sewer and carried out into deep water.

Much of the sewage of the other parts of the city is flooded over four irrigation-farms, which are profitable, but the sources of considerable complaint. It is proposed to build another long intercepting sewer on the southern side of the city.

The ventilation of the sewers is deficient, and, as in Glasgow, typhoid fever is observed in the houses of the better class on the high land, at the tops of the sewers. Typhus is not uncommon in the "Cowgate" and "Canongate," where the poorest classes live.

Three inspectors are kept constantly employed looking after house-drains, and compelling house-owners to repair breaks and imperfections.

Dublin has, in the main, good sewers, but their discharge into the river Liffey is a source of so great annoyance that many business men have been obliged to remove their offices from that part of the city. The system of intercepting sewers with two siphons across the Liffey, proposed by Messrs. Bazalgette and Carrick in their report, it is generally supposed will be adopted, at a cost of 500,000 pounds. The sewage is to be discharged at deep water, several miles from the city, and at a point where it can be utilized by irrigation, if it shall be thought necessary or best to do so. The sewers are well flushed, but not thoroughly ventilated, an evil which they mean to correct.

Paris. — The enormous sewers of this city are beautiful specimens of engineering skill; but it is doubtful whether they are as satisfactory in a sanitary point of view as those built upon the principles laid down by English and American engineers. The two intercepting sewers, one with a siphon, under the Seine discharge at points quite below the city. The street refuse passes directly into the sewers through untrapped pipes, the idea being that it can thus be removed more cheaply and with less obstruction to travel and traffic than from the streets. There is always,

therefore, quite a large deposit in the sewer; but it is not allowed to remain long, six hundred and seventy men being constantly employed to remove it. Originally, water-closets were not connected with the sewers, but the rule has been changed with reference to the newer houses, and 1,500 of them now discharge into sewers instead of cesspools. Flushing is provided for by the large quantities of water used daily to wash the streets; and the street-gullies serve as free ventilators.

The irrigation with sewage is unfortunately at present carried out on a very small scale and at considerable pecuniary loss to the city, although the farmers, who pay nothing for the sewage, make some profit.

The telegraph-wires and water-pipes are laid along the tops of the arches of the sewers, many of which really resemble subterranean streets in their size. The only objection to this arrangement is that during the flooding of the sewers by storm-water these pipes could not be readily repaired if injured. The water in the sewers has very seldom been high enough, however, to make any such thing possible. Gas-pipes are laid in the streets, as with us, and not in the sewers, for fear of explosions.

There are two principal sources of water-supply beside the two Artesian wells (which latter yield a very small proportion of the whole quantity used). The water from the Seine and the Dhuis is potable, while that from the Marne is used only for washing streets and such purposes.

Frankfort-on-the-Main. — A new system of sewers was begun in 1867, under the distinguished English engineer, Mr. W. Lindley. The old sewers are to be filled up and destroyed. The plans show the highest skill. The mechanical execution is most admirable, and no other large city in Europe is so perfectly sewered. The sewage is discharged in the middle of the river Main, under water, and at some distance below the city. The sewers are put at great depth in order to drain the soil, and to take advantage of the ground water for flushing. The street-gullies are all trapped, and no dust or sand is allowed to get in from that source.

Flushing is secured by means of three hundred flushing-gates in the course of the sewers, which are closed long enough to get sufficient head, and then suddenly opened. Ventilation is to be got by soil-pipes carried through the roofs, by rain-water pipes, and by three high ventilating towers, one of which is the chimney of a manufactory. The river is so broad and rapid that it is not likely to be seriously contaminated for some years. Nevertheless part of the original plan provides for sewage irrigation, and the present outlet is therefore placed near land suitable for that purpose.

Hamburg was the first city which had a complete systematic sewerage-system throughout according to modern ideas. How far that was in advance of the rest of the world, in 1843, when the work was undertaken, may be inferred from the fact that there are no real advances in new principles from that time up to the present day. The sewers, unlike those of Frankfort, are made on the "open system," that is, the rain-water spouts are all untrapped to serve as ventilators to the sewers; the street-gullies are also without traps, and

there are gratings for ventilation opening into the street. It is very rare that any of the latter are sources of complaint, inasmuch as the sewers are kept so clean that there are seldom any foul-smelling gases.

The great feature in Hamburg, however, is the weekly flushing at low tide by letting the waters of the Binnen Alster flow through the sewers with great force. There are also flushing-gates for washing out the branch sewers. This whole process is carried out so completely that the siphon under the river Alster has not required cleaning since it was built, in 1845.

A senator, one of Lindley's strongest opponents when he proposed his plans for sewering the city, came to him three years after a certain sewer had been completed, to ask as to the position of its provisional outlet, which was under water and near his own house, where the stream was only a hundred feet wide. He said that he could neither see nor smell anything, and was greatly surprised when the point of discharge was shown to him. Twenty-five years after the sewers were completed, they were found by a commission of experts to be clean and almost without odor.

The river Elbe is too large to be seriously contaminated by the sewage of Hamburg.

Munich is just abandoning the old system (or rather want of system), which is really very imperfect, to build new sewers, under an English engineer, formerly assistant of Mr. Lindley; so that the plan of either Hamburg or Frankfort will probably be closely followed.

Dusseldorf and *Crefeld* are at work on the Frankfort pattern, and *Stuttgart* is just inaugurating similar works.

Dantzic has recently completed a system of sewerage under the celebrated German engineer Wiebe, of which the main features are two large intercepting sewers, each connected with pumping-works by a siphon, frequent flushing from the river Radaune, and free ventilation into the streets by gratings without charcoal filters. The storm-water is discharged by overflows into the river Mottlau. The sewage is carried five miles from the city and utilized on an irrigation farm.

Berlin is to have a sewerage system, to be finished in 1883, by which the sewage is to be carried off to the outskirts of the city, pumped, and utilized on five different irrigation-farms.

New York now discharges most of its sewage in the docks, from which there are many complaints. The old, badly constructed sewers are making over, and plans have been approved by the authorities for long intercepting sewers, to discharge the sewage at deep water, and by only two outlets.

Brooklyn has very finely constructed sewers, on an excellent system. The outlets have been located with reference to avoiding a nuisance (not in all cases entirely successful), and there is very little complaint against them. It is the only city in this country where free ventilation is got by openings into the streets. Many of these gratings were examined, and there were only a few where any smell could be detected six feet from the surface of the streets. There is very seldom any complaint of them, and very many people fail to discover that they exist at all.

Philadelphia is poorly provided with sewers, a large part of the city having none at all.

Baltimore still follows the custom begun in Paris, of forbidding connections between the water-closets and the few sewers that exist. Most of the first-class dwellings and the hotels have water-closets discharging into cesspools, made in the porous soil of the city. In some cases their liquid contents are emptied into the sewers. Street-washings and the slop-water discharged by the sewers, however, have made the basin very filthy and foul-smelling.

Near the city the tide rises and falls only one foot and a half, an incurable difficulty in the way of disposing of the sewage within the city limits. Already a main-drainage scheme is talked of, to take all the sewage to a point several miles below the city, and to abolish the cesspools; but it has not yet assumed a definite form.

At *Washington* enormous main sewers are building in the courses of the natural streams, the outlets to be at deep water instead of being on the flats, as at present. This plan has some advantages in draining the soil, as natural drainage-areas are followed; but they are much more than counterbalanced by having the sewers pass across house-lots, through cellars, etc., so as to be difficult of access for repairs, and to contaminate the air of houses in case of accident. In case of excessive rain, too, it is generally difficult to prevent their being filled to overflowing.

Three of the pumping-stations of London, and those of Stratford, Birmingham, Paris, Dantzic, Bedford, Crewe and Leeds have been visited during the past summer, and have been found invariably to be free from offensive odors outside of the buildings containing the pumps. In most cases, too, the odor was only very slight within the buildings.

APPENDIX B.

Public hearings were held by the Commission on the afternoons of July 9th and 10th, and many letters have been received from gentlemen in various parts of the city from time to time. Our attention has in this way been directed to many local evils, all of which have been investigated carefully.

The statements made in these ways are not published here, for want of space, but they have been preserved for reference, if needed.

We quote the opinions of a few of the leading physicians, which, it is thought, represent very fairly the position of the medical profession: —

"I am most deeply convinced of the importance of an immediate improvement in the system of sewerage. Immense as the outlay for any substantial change must be, that outlay is as nothing in comparison

to the cost in lives and in the resources of the community, which a continuance of the present evil entails.

"In the presence of an hourly poisoning such as the air undergoes, the death-rate cannot fail to be raised, and medical measures for the preservation of the public health will have but little effect."

DR. J. P. REYNOLDS.

"My views are that it (*i.e.*, a change in our system of sewerage) it of such necessity, and should be of such an extended character, thas the expenditure of an immense amount of money (say several millions of dollars) can alone accomplish any practical good."

DR. R. M. HODGES.

"The sewage should either be pumped, diluted and irrigated, or discharged a long way below the city in tide water.

"The Roxbury canal (Albany st.) is an open sewer, stinking and black at high water, highly deleterious to the City Hospital, and to the South End. It is sprinkled over our streets, and the smell is perceptible summer evenings after the last watering."

DR. D. W. CHEEVER.

"It is impossible to cite individual cases of disease which are distinctly owing to bad drainage. I do not know that I ever saw such; but there is no fact better established by general experience than that foul air is unfavorable to health, and that it aggravates epidemics when they occur.

"That the whole atmosphere of our city has, through imperfect drainage, become at times too foul for endurance, is too patent a fact for any one to dispute, and should take precedence in public attention before any other object of public interest. In my own immediate neighborhood I have had an opportunity to observe one noisome source of pollution in the emptying of drains into Charles river, at the foot of Chestnut and Mt. Vernon streets. During the cold weather, and especially while the river is covered with ice, the stench is less noticeable.

"At high tide there is no trouble. For an hour before and after low tide it is always present, more at certain conditions of the atmosphere than at others, and extending in one direction or another, according to the wind. On a still day, at low water, the foul gases may be seen bubbling from the surface in all directions.

"The eddy created by the stream, and the angle of the wall, seems to deposit the discharge from the drains at this point, for I have repeatedly examined the opposite flats, in the neighborhood of the oyster-beds, and could perceive nothing of the kind there, the mud having no odor other than that peculiar to salt marsh. It would seem as if dredging, unless constantly repeated, could accomplish little here. The nuisance is only a reappearance of the state of things which existed in Charles street before Brimmer street was filled in. The only effectual remedy will be to fill in the angle at the foot of Chestnut street, rounding the shore so as to avoid the eddy, and carrying the drains to some point below low tide, whence their contents should be surely carried out to sea; and this is what must be done with regard to every drain in the city if we wish to protect ourselves against this insufferable nuisance; and it is to be hoped that no half-way measures will be adopted, but that a well-systemized plan, resting upon the best information that can be obtained on the subject, will be resolutely carried out."

DR. C. E. WARE.

Appendix C.

SUMMARY OF CONDITION OF SOUTH END CELLARS DURING STORM OF THE NIGHT OF JUNE 9, 1875.

I.

DISTRICT DRAINED BY DOVER STREET SEWER.

STREETS.	1. Number of Cellars examined above Grade 8. Dry. Living Room.	1. Dry. Store Room.	1. Dry. Bare Ground.	1. Wet. Living Room.	1. Wet. Store Room.	1. Wet. Bare Ground.	1. Average Depth of Water in the Wet Cellars.	2. Number of Cellars examined above Grade 7, and below 8. Dry. Living Room.	2. Dry. Store Room.	2. Dry. Bare Ground.	2. Wet. Living Room.	2. Wet. Store Room.	2. Wet. Bare Ground.	2. Average Depth of Water in the Wet Cellars.	3. Number of Cellars examined above Grade 6, and below 7. Dry. Living Room.	3. Dry. Store Room.	3. Dry. Bare Ground.	3. Wet. Living Room.	3. Wet. Store Room.	3. Wet. Bare Ground.	3. Average Depth of Water in the Wet Cellars.	4. Number of Cellars examined above Grade 5, and below 6. Dry. Living Room.	4. Dry. Store Room.	4. Dry. Bare Ground.	4. Wet. Living Room.	4. Wet. Store Room.	4. Wet. Bare Ground.	4. Average Depth of Water in the Wet Cellars.	5. Number of Cellars examined below Grade 5. Dry. Living Room.	5. Dry. Store Room.	5. Dry. Bare Ground.	5. Wet. Living Room.	5. Wet. Store Room.	5. Wet. Bare Ground.	5. Average Depth of Water in the Wet Cellars.	6. Total number of Cellars examined. Dry. Living Room.	6. Dry. Store Room.	6. Dry. Bare Ground.	6. Wet. Living Room.	6. Wet. Store Room.	6. Wet. Bare Ground.	6. Average Depth of Water in the Wet Cellars.
Dover Street (south side)	....	5	....	....	....	....	....	....	1	....	....	....	....	....	....	....	4	....	....	1	....	1.5	....	5	....	....	6	....	0.4	....	6	....	....	1	....	0.1	....	21	....	....	8	....	0.5
Groton Street	9	....	....	....	....	....	....	6	....	....	....	....	....	....	1	....	....	....	1	....	1.0	....	1	....	....	1	....	2.0	....	....	....	....	....	....	....	15	1	....	....	2	....	1.5
Dwight Street	....	....	....	....	....	....	....	....	3	....	....	3	....	0.2	....	3	....	....	20	....	0.9	....	....	....	....	19	....	1.1	....	....	....	....	2	....	1.3	....	5	....	....	44	....	0.9
Medford Court	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4	....	....	1	....	0.4	....	....	....	....	....	....	....	....	....	....	....	....	1	....	0.2	2	4	....	....	7	....	0.4
Acton Street	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	4	....	0.9	....	....	....	....	3	....	1.0	....	....	....	....	1	....	2.6	....	1	....	....	5	....	1.1
Wells Place	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	2	....	....	3	....	0.3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	3	....	0.3
Bradford Street	1	1	....	....	1	....	1.0	....	15	1	1	8	....	0.2	....	3	....	....	6	....	0.4	....	....	....	....	1	....	1.5	....	....	....	....	....	....	....	2	22	1	....	16	....	0.4
Milford Street	....	9	....	....	....	....	....	....	2	....	....	1	....	0.1	....	....	....	....	7	....	1.3	....	....	....	....	22	....	1.3	....	....	....	....	1	....	1.0	....	11	....	....	50	....	1.2
Hanson Street	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	7	....	0.9	....	....	....	....	20	....	1.4	....	....	....	....	1	....	1.0	....	1	....	....	28	....	1.3
Waltham Street	....	4	....	....	....	....	....	....	1	....	....	....	....	....	....	2	....	....	9	....	0.7	....	....	....	....	19	....	1.4	....	....	....	....	2	....	0.7	....	7	....	....	30	....	1.1
Union Park Street	....	1	....	....	1	....	0.1	....	1	....	....	2	....	1.3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	3	....	0.9
Union Park	....	1	....	....	....	....	....	....	....	....	....	2	....	0.2	....	2	....	....	20	....	0.6	....	....	....	....	21	....	0.7	....	....	....	....	2	....	0.9	....	3	....	....	45	....	0.6
Upton Street (north side)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	5	....	1.0	....	....	....	....	10	....	1.2	....	....	....	....	....	....	....	....	1	....	....	15	....	1.1
Pelham Street	....	8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	0.7	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	2	....	0.7
Taylor Street	....	....	....	....	....	....	....	1	1	....	....	....	....	....	....	1	....	....	2	....	0.4	....	....	....	....	4	....	1.7	....	....	....	....	1	....	2.0	3	2	....	....	7	....	1.4
Bond Street	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	7	....	1.1	....	....	....	....	7	....	1.9	....	....	....	....	14	....	1.5
Ringgold Street	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4	....	0.7	....	....	....	....	3	....	0.6	....	....	....	....	7	....	0.6
Washington Street	1	6	....	....	1	....	0.3	....	7	....	....	4	....	0.2	....	....	....	....	1	....	1.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	13	....	....	6	....	0.3
Shawmut Avenue	....	2	....	....	1	....	0.6	....	5	....	....	1	....	2.0	1	6	....	....	20	....	0.7	....	....	....	....	15	....	1.1	....	....	....	....	5	....	0.7	1	13	....	....	42	....	0.9
Tremont Street	....	1	....	....	....	....	....	....	1	....	....	4	....	0.9	....	1	....	....	16	....	1.2	....	....	....	....	13	....	1.2	....	....	....	....	....	....	....	....	3	....	....	33	....	1.2
Dartmouth Street	....	....	....	....	....	....	....	....	....	....	....	4	....	0.4	....	....	....	....	6	....	0.6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	10	....	0.5
Montgomery Street	....	1	....	....	....	....	....	....	2	....	....	2	....	0.1	....	3	....	....	4	....	0.1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6	....	....	6	....	0.1
TOTAL	14	48	....	....	4	....	0.5	9	41	1	1	31	....	0.6	1	36	....	....	140	....	0.8	....	6	....	....	165	....	1.2	....	11	....	....	27	....	1.1	24	137	1	....	368	....	0.8

7. REMARKS.

Note. — Of the Wet Cellars in these columns, the following were the maximum and minimum depths.

	Maximum.	Minimum.
Column 1.	1.0 ft.	0.1 ft.
2.	2.0	0.1
3.	2.5	0.1
4.	3.0	0.1
5.	2.6	0.1

Number of Cellars not examined, **221**, all of which are reported to be above Grade **8**.

SUMMARY OF CONDITION OF SOUTH END CELLARS DURING STORM OF THE NIGHT OF JUNE 9, 1875.

II.

DISTRICT DRAINED BY DEDHAM STREET SEWER.

STREETS.	1. Above Grade 8. Dry. Living Room.	1. Above Grade 8. Dry. Store Room.	1. Above Grade 8. Dry. Bare Ground.	1. Above Grade 8. Wet. Living Room.	1. Above Grade 8. Wet. Store Room.	1. Above Grade 8. Wet. Bare Ground.	1. Average Depth of Water in the Wet Cellars.	2. Above Grade 7, and below 8. Dry. Living Room.	2. Above Grade 7, and below 8. Dry. Store Room.	2. Above Grade 7, and below 8. Dry. Bare Ground.	2. Above Grade 7, and below 8. Wet. Living Room.	2. Above Grade 7, and below 8. Wet. Store Room.	2. Above Grade 7, and below 8. Wet. Bare Ground.	2. Average Depth of Water in the Wet Cellars.	3. Above Grade 6, and below 7. Dry. Living Room.	3. Above Grade 6, and below 7. Dry. Store Room.	3. Above Grade 6, and below 7. Dry. Bare Ground.	3. Above Grade 6, and below 7. Wet. Living Room.	3. Above Grade 6, and below 7. Wet. Store Room.	3. Above Grade 6, and below 7. Wet. Bare Ground.	3. Average Depth of Water in the Wet Cellars.	4. Above Grade 5, and below 6. Dry. Living Room.	4. Above Grade 5, and below 6. Dry. Store Room.	4. Above Grade 5, and below 6. Dry. Bare Ground.	4. Above Grade 5, and below 6. Wet. Living Room.	4. Above Grade 5, and below 6. Wet. Store Room.	4. Above Grade 5, and below 6. Wet. Bare Ground.	4. Average Depth of Water in the Wet Cellars.	5. Below Grade 5. Dry. Living Room.	5. Below Grade 5. Dry. Store Room.	5. Below Grade 5. Dry. Bare Ground.	5. Below Grade 5. Wet. Living Room.	5. Below Grade 5. Wet. Store Room.	5. Below Grade 5. Wet. Bare Ground.	5. Average Depth of Water in the Wet Cellars.	6. Total Number of Cellars Examined. Dry. Living Room.	6. Total Number of Cellars Examined. Dry. Store Room.	6. Total Number of Cellars Examined. Dry. Bare Ground.	6. Total Number of Cellars Examined. Wet. Living Room.	6. Total Number of Cellars Examined. Wet. Store Room.	6. Total Number of Cellars Examined. Wet. Bare Ground.	6. Average Depth of Water in the Wet Cellars.	7. Remarks.
Upton Street (south side)	2	1	....	....	1	....	1.6	....	....	....	....	9	....	1.1	....	....	....	....	4	....	2.1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	1	....	....	14	....	1.4	
West Dedham Street	....	4	....	....	6	....	1.3	....	1	....	....	8	....	1.2	....	....	....	....	3	....	0.9	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5	....	....	16	....	1.0	
West Canton Street	3	14	....	....	2	....	0.6	....	....	....	....	7	....	0.7	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1.0	....	....	....	....	....	....	3	14	....	....	10	....	0.7	
West Brookline Street	....	12	1	....	2	....	0.1	....	....	....	....	3	....	1.2	....	....	....	....	1	....	0.2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	12	1	....	6	....	0.8	
Pembroke Street	....	1	1	....	1	....	6.1	....	....	....	....	6	....	1.1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	1	....	7	....	0.9	
West Newton Street	....	8	....	....	11	....	0.3	....	....	....	....	5	....	0.7	....	....	....	....	1	....	0.1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	8	....	....	17	....	0.6	
Rutland Street	1	....	....	....	3	....	1.3	....	....	....	....	9	....	0.8	....	....	....	....	4	....	0.9	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	16	....	0.9	
West Concord Street	....	1	....	....	2	....	0.2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	2	....	0.2	
Concord Square	....	4	....	....	5	....	0.8	....	....	....	....	9	....	0.8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4	....	....	14	....	0.8	
Worcester Street	....	1	....	....	6	....	0.8	....	....	....	....	1	....	1.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	7	....	0.7	
West Springfield Street	....	....	....	....	7	....	0.9	....	....	....	....	6	....	1.4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	13	....	0.9	
Chester Square	....	1	....	....	4	....	0.3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	4	....	0.2	
West Chester Park	....	7	....	....	9	....	0.6	....	....	....	....	1	....	0.8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	7	....	....	10	....	0.6	
Shawmut Avenue	....	4	....	....	5	....	0.9	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4	....	....	4	....	1.2	
Tremont Street	5	9	....	....	12	....	0.6	....	....	....	....	30	....	0.8	....	....	1	....	14	....	0.8	....	....	1	....	1	....	2.0	....	....	....	....	....	....	....	....	5	9	1	....	57	....	0.8	
Additional, Tremont Street	....	2	....	....	3	....	0.4	....	....	....	....	10	....	0.4	....	....	....	....	16	....	0.8	....	....	....	....	5	....	1.3	....	....	....	....	....	....	....	....	2	....	....	34	....	0.7	
Additional, West Canton Street	....	....	....	....	....	....	....	....	1	....	....	1	....	0.1	....	....	....	....	1	....	0.1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	2	....	0.1	
Additional, West Brookline Street	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	1	....	....	3	....	0.8	....	....	....	....	1	....	2.0	....	....	....	....	....	....	....	....	2	....	....	5	....	1.0	
Additional, Pembroke Street	....	....	....	....	1	....	0.1	....	....	....	....	2	....	0.6	....	....	....	....	3	....	1.7	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6	....	1.1	
Additional, West Newton Street	....	....	....	....	2	....	1.6	....	....	....	....	6	....	0.8	....	....	....	....	2	....	1.5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	10	....	1.1	
Additional, Shawmut Avenue	....	....	....	....	2	....	1.0	....	....	....	....	4	....	0.9	....	1	....	....	8	....	0.6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	14	....	0.7	
TOTAL	11	69	1	....	82	....	0.7	....	3	....	....	116	....	0.9	....	2	1	....	8	....	0.9	....	....	1	....	8	....	1.6	....	....	....	....	....	....	....	....	11	74	3	....	268	....	0.8	

NOTE. – Of the Wet Cellars in these columns the following were the maximum and minimum depths.

	Maximum.	Minimum.
Column 1.	1.5 ft.	0.1 ft.
2.	2.0	0.1
3.	2.5	0.1
4.	2.5	0.2
5.	—	—

Number of Cellars not examined, **527**, all of which are reported to be above Grade **9**.

APPENDIX D.

ACCOUNT OF SOME EXPERIMENTS MADE TO DETERMINE THE COMPOSITION OF THE GROUND-ATMOSPHERE IN PROXIMITY TO DECAYING ORGANIC MATTER.

BY PROFESSOR WM. RIPLEY NICHOLS.

The locality chosen for the experiments was on the Back-bay lands, on the vacant lot next to the Institute of Technology. A pit was dug about 6 feet square and 5½ feet deep, and on May 13th it was filled to within about a foot of the top with the semi-liquid material taken from one of the manholes in the Church-street sewer. The sand and other heavier portions settled to the bottom of the pit, and, as soon as the water had soaked away sufficiently, fine clean gravel was thrown over the material; as the mass gradually became more compact, an additional quantity of gravel was thrown in, until in the course of about two weeks the pit was filled up to the level of the surrounding ground, and the top of the deposit was about 18 inches below the surface. In order to obtain air for examination there were inserted into this covering of gravel two glass tubes, one (A) to a depth of 14 inches from the surface of the ground, another (B) to the depth of 8 inches. Owing to the yielding nature of the buried matter and to the fact that the covering continued to settle slowly, it is not possible to state just how far above the top of the decomposing mass the glass tubes ended; we may say that the bottom of the tube A was within some 6 inches, of the tube B within some 12 inches. On Sept. 13, the surface of the ground having sunk some 3 inches, that quantity of gravel was thrown upon it. I may add that the spot where the experiments were conducted was covered by a shed somewhat loosely constructed, so that there was a free circulation of air above the ground. Further, the level of the ground-water is at this place generally from 4 to 5 feet below the surface.

As to the composition of the matter which was buried, it was difficult to obtain a fair sample of the whole, but some of the upper portion of the deposit, on examination, gave moisture 69 per cent.; ammonia, about $\frac{7}{10}$ of one per cent.; sulphuretted hydrogen expelled by boiling with water, about $\frac{1}{10}$ of one per cent. Some of the material after being dried at the temperature of boiling-water, was found to contain 0.46 per cent. of nitrogen. When the pit had been filled, and before the covering of gravel was thrown in, there was, at first, little disagreeable odor, but when the mass was covered it was undergoing decomposition, and had become somewhat offensive; bubbles of gas were escaping in some abundance. Beside the glass tubes already mentioned, which were intended to give the means of drawing air from different depths, a third tube (C) was connected with a glass funnel, which funnel was placed upon the surface of the ground, near the other tubes.

On the 5th of June the examination of the air in the soil and at the surface of the ground was begun, and examinations have been made at intervals until the present date (Nov. 10). The general

results of the examinations may be summed up as follows: The gaseous products of decay which might be expected to be produced from such a mixture of animal and vegetable matter are sulphuretted hydrogen, ammonia, carbonic acid and marsh-gas; the first, sulphuretted hydrogen, was not detected even in the air taken 14 inches from the surface of the ground, *i.e.*, less than 6 inches from the top of the decaying matter; ammonia was not found in any appreciable amount; there seemed to be a small amount of marsh-gas formed (see below), and of carbonic acid a very large quantity was produced. The amount of carbonic acid was greatest in the neighborhood of the decaying matter, and decreased in amount towards the surface of the ground. The maximum amount was observed during July and August; observations made since the first of October show that the amount is steadily decreasing. Also, since the first of October marsh-gas has not been observed in the ground-atmosphere. At no time was the air in the shed a few feet from the ground observed to be in any way affected, and, indeed, this would be expected, as the gas arising from the surface of the ground and diffusing into the surrounding atmosphere would be so diluted as to escape observation.*

The determinations of carbonic acid were made by passing a measured quantity of air through baryta-water of known strength, and determining the amount of baryta remaining as hydrate by titration, in the usual manner. The amounts found are indicated in the following table, where are introduced also, for the sake of comparison, some determinations of the amount of carbonic acid in the gravel of the Back bay, at the depth of 10 feet (Tube D).†

* For an illustration of the rapidity of the diffusion of carbonic acid gas, see certain observations of Pettenkofer, quoted in the Sixth Annual Report of the Mass. State Board of Health (1875), page 224.

† For a description of the locality from which this air is taken, and for an account of determinations previously made at the same spot, see the Sixth Annual Report of the State Board of Health (1875), page 215.

Amount of Carbonic Acid expressed in number of volumes in 1,000 volumes of Air.

DATE.	Tube A. Air taken 14 inches from surface of ground.	Tube B. Air taken 8 inches from surface of ground.	Tube C. Air taken at surface of ground.	Tube D. Air taken at a depth of 10 feet from the surface of ground in another locality.
June 5	87.79	52.49	....	....
7	....	....	12.49	....
12	93.34	63.80	13.05	....
18	....	....	....	7.58
19	96.41	59.65	20.34	....
25	....	....	....	15.28
26	113.76	75.41	20.85	....
July 5	122.85	....	25.56	....
8	....	....	....	15.79
16	119.54	....	....	....
17	....	....	23.13	....
Aug. 4	112.33	....	....	....
5	....	....	21.78	....
15	....	....	....	14.66
21	116.14	....	22.19	....
Oct. 1	....	....	....	8.16
5	75.60	....	6.69	....
9	66.70	....	6.12	....
16	62.33	....	5.56	....
Nov. 8	....	....	....	4.22
10	30.93	....	3.54	....

Note. — The amount of carbonic acid ordinarily present in the air may be taken as from 3 to 4.5.

On several occasions more complete examinations of the air were made with the following results: * —

* These determinations were made with a modified form of Doyère's gas apparatus, as described by C. W. Hinman, Amer. Jour. Sci. (3) viii. (1874), page 182. To test the accuracy of the apparatus the following examinations were made of out-door air: —

	I.	II.	III.	IV.	Normal air about
Oxygen and Carbonic acid,	20.964	20.793	20.799	20.914	Oxygen, 20.96
					Carbonic acid, 0.04
Nitrogen,	79.036	79.207	79.201	79.086	Nitrogen, 79.00
	100.000	100.000	100.000	100.000	100.00

The apparatus would seem to give results sufficiently accurate for this purpose, except that for small amounts of carbonic acid the results are less accurate than those obtained by the baryta method. The oxygen was determined by absorption with alkaline pyrogallate.

Tube A (14 inches from the surface).

	June 21.	June 26.	Oct. 16.	Nov. 10.
Oxygen,	14.76	13.49	15.39	16.95
Carbonic acid,	11.51	13.28	6.18	3.82
Nitrogen,	73.73*	73.23*	78.44	79.23
	100.00	100.00	100.00	100.00

Tube C (at surface of ground).

	Oct. 16.	Nov. 10.
Oxygen,	19.595	19.798
Carbonic acid,	0.614	0.387
Nitrogen,	79.791	79.815
	100.000	100.000

The evidence of the presence of marsh-gas in the air of the gravel overlying the decomposing matter is as follows: A stream of the air from the tube A, after being thoroughly dried and freed from carbonic acid, was passed through a heated glass tube containing oxide of copper (preivously thoroughly ignited in a stream of dry air free from carbonic acid). The air issuing from the tube was found to contain both water and carbonic acid, which, under these circumstances, must have come from the combustion of some compound or compounds containing carbon and hydrogen. We might naturally expect marsh-gas to be present, and when the amount of water formed was determined by absorption in chloride of calcium, and the carbonic acid by means of standard baryta, it was found that the amounts of carbon and hydrogen were nearly in the proportion in which they exist in marsh-gas; the agreement was as close as could be expected in the case of such small quantities.†

* Including a small amount of marsh-gas.

† Of course other hydrocarbons, if present, would act similarly, and if carbonic oxide were present it would by this method of analysis be burned and appear as carbonic acid. Carbonic oxide has been stated to be among the products of the decomposition of organic matter. (Eulenberg. Lehre von den schädlichen und giftigen Gasen. Braunschweig, 1865, p. 30.) Boussingault (Comptes Rendus, liii. 1861, p. 862) asserts that carbonic oxide (with marsh-gas) is given out by the leaves of certain plants, especially by water-plants, under the influence of sunlight; and a recent writer (Kedzie, — Trans. Mich. State Med. Soc. 1875, p. 303) even suggests that carbonic oxide may be a potent factor in the miasmatic exhalations from marshes. carbonic oxide is stated to have been found among the gases from certain foul waters; Bunsen, however (Bunsen's Gasometry, English edition, 1857, pp. 101–103), did not find it in the gases from a muddy pool, the examination of which he records, nor did Websky (Erdmann's Journ. für prakt. Chemie, xcii. pp. 65–96) find it in his examination of the gases arising from a pool in a peat bog. Under the circumstances of this particular case, I am inclined to doubt the probability of the presence of carbonic oxide; at any rate no amount at all considerable could be present without increasing the amount of carbon found as compared with the amount of hydrogen.

The results of the testing for marsh-gas are as follows: —

TUBE.	DATE.	Amount of air taken expressed in cubic centimeters	Weight of Carbon found expressed in milligrams.	Weight of Hydrogen found expressed in milligrams.	Weight of marsh-gas calculated from the carbon found.	Volume of marsh-gas in 1,000 parts of air taken.
A (14 inches from surface of ground),	June 24.	2340	7.00	2.50	8.17	5.26
	July 1.	2000	11.61	3.90	13.55	10.28
	Aug. 26.	4300	2.27	0.66	2.65	0.92
	Oct. 9.	2000	0	0	0	0
C (at surface of ground),	June 24.	3000	Trace.	. .	. .	Trace.
Outer air (in shed),	June 24.	3000	0	0	0	0

In the foregoing examinations and in those detailed in Appendix F, to follow, I have been aided by my assistant, Mr. W. E. Nickerson, and by Mrs. R. H. Richards, my indebtedness to whom I take pleasure in here acknowledging.

WM. RIPLEY NICHOLS.

APPENDIX E.

Experiments with pipes driven into the ground in various parts of the city, made during July, August, September, October and November of the present year, show that the water in the soil of the flat parts of Boston stands at a level from six and one-half to eight feet below the levels of the streets, and very often above the spring of the arch of the sewer.

On the high land, where the soil is loose and porous, the water stands much lower. With a clay subsoil near the surface, however, the soil is much more moist, especially at the foot of the hill, where the surface-drainage of the higher land is more or less collected.

No experiments were made in the "South Cove" and "Mill Pond" districts, because ordinary observation demonstrates the fact that the tide-water flows in and out among the old wharves, oyster shells, etc., which make up a large part of the filling-in of those parts of the city. The tide flows in and out, too, rather freely near Otter street, on Brimmer street, and probably in a large part, if not all, of the city which lies outside of the "Mill Dam" and Charles street.

In all of the "made land," the level of the water rises some inches at high tide, showing that the action of the sewers as drains is prevented at that time. On Albany street, this rise of

the water amounted to one foot; in one part of the "made land" at the West End *it amounted to three feet.*

The general conclusion from these experiments, which will be seen by the following table, is that *soil-mixture is a serious evil in all the low parts of our city.*

An intercepting system of sewers would lower the level of the ground-water several feet, but it is doubtful whether it could be got below grade 5, unless the whole city be surrounded with a water-tight dike; nor is that necessary.

Relation of Ground Water to the Soil in Boston.

STATION.	LOCALITY.	Grade of ground-water above O, or low tide.	Grade of ground-water above the bottoms of the sewers.	Grade of ground-water below the levels of the streets.	Extreme rise of ground-water from heavy rains.
A.	Northern side Beacon Hill	40.	3.5	6.5	1.5
B.	Outside of "Mill Dam" . .	10.	5.	7.	2.5
C.	Near Park Square	7.5	1.5	7.25	.5
D.	" " "	6.75	1.25	6.5	1.5
E.	Lower part Boylston st. .	7.5	4.	7.	1.
F.	Institute of Technology . .	8.	4.75	7.	1.25
G.	South End	8.5	1.5	7.	1.25
H.	Boston Neck	9.25	2.	7.75	1.5
I.	South End	6.	4.	7.5	1.5
K.	" "	3.75	4.	4.*	.5
L.	" "	9.5	5.	7.5	1.
M.	Albany street	10.5	3.	7.	.5
N.	Back Bay	8.5	6.	8.	1.
O.	" "	6.5	4.	†10.	.5
P.	West of Charles street . .	9.5	2.5	7.5	3.5
R.	West side Beacon Hill . .	No water found ten feet below the surface of			
S.	" " " " . .	the ground.			

APPENDIX F.

The influence of sewers on the soil of cities has attracted so much attention, especially since the observations of Pettenkofer with regard to the badly-constructed sewers of Munich, that it has been thought advisable to make some experiments, to see whether *well-constructed* sewers exercised any appreciable influence in con-

* Calculated from the level of the back street.
† This observation was incomplete and not to be relied upon.

taminating the ground atmosphere in their vicinity. As far as the observations have extended, the effect of the sewers seems to be inconsiderable, as the following notes by Professor Nichols will show. Similar results have been obtained in Munich during the past summer.

Account of some Examinations of the Ground Atmosphere in the Neighborhood of Sewers.

For this investigation the old Roxbury sewer, on Dearborn street, was chosen as furnishing as instructive an example as could be found of a sewer which has been in use some years. The sewer was built in 1860, and the bottom is not impervious to water. A pipe was driven into the ground in the neighborhood of the sewer, and the opening of the pipe was calculated to be about a foot and a half from the sewer, and on the level with the spring of the arch. This would be ten feet from the surface of the street. Examination failed to detect sulphuretted hydrogen* or marsh-gas. Carbonic-acid determinations were made as follows: —

	Number of volumes of carbonic acid in 1,000 volumes of air.
October 6,	35.31
" 13,	34.63
November 12,	23.46

The following more complete examinations were made: —

	Oct. 13.	Nov. 16.
Oxygen,	17.21	19.41
Carbonic Acid,	3.36	1.59
Nitrogen,	79.43	79.00
	100.00	100.00

An examination was also made of the air in the ground near the Berkeley-street sewer (at the corner of Newbury street). In this place it was impossible, on account of the water in the ground, to draw the air from a point as close to the sewer as in the previous case. The air was actually taken about nine feet six inches from the surface of the street, and the spring of the arch of this sewer is twelve feet below the level of the street.

The examinations showed,

	Nov. 11.	Nov. 15.
Oxygen,	19.54	19.57
Carbonic Acid,	1.15	1.27
Nitrogen,	79.31	79.16
	100.00	100.00

* For a description of the method of sinking the pipes see Sixth Annual Report of Mass. State Board of Health (1875), page 214. In testing for sulphuretted hydrogen the air is drawn through a *glass* pipe; for the carbonic-acid determinations a lead pipe was used in this case as being more convenient.

These examinations would seem to indicate that, with the exception of an increased amount of carbonic acid, there is no evidence of the contamination of the ground atmosphere by the sewers, and it would seem highly improbable that injurious emanations from underground sewers should ever reach the air above by passing through the soil.

WM. RIPLEY NICHOLS.

APPENDIX G.

SUMMARY OF EXPERIMENTS WITH FLOATS MADE UNDER THE DIRECTION OF C. W. FOLSOM, C. E.

From STATION I. (opposite the mouth of the Binney-street sewer, Cambridge, in Charles river), the upward current, starting at low water, may carry the floats in neap tides to Brookline bridge (two miles and a quarter); with a great prospect, however, of being detained in the eddies near Beacon street. The downward current, starting at high water, will carry the floats down at least as far as Bird Island (three miles), Castle Island (four miles), or Spectacle Island (five miles and a half); with considerable probability, on the return tide, of being carried on to South Boston or East Boston flats.

From STATION II. (off South Boston or City Point), the upward current, starting at low water, will generally ground the floats upon South Boston flats, or even on the north side of South Boston (two miles); with a possibility of getting up to the neighborhood of Boston and East Boston wharves (two miles and a half). The downward current, starting at high water, will carry the floats generally to the narrows between Long Island and Deer Island, (three miles); with a strong probability of being carried up toward Apple Island on the return flood.

From STATION III. (off Castle Island), the upward current, starting at low water, passes up pretty nearly by the main ship channel, and extends a considerable distance up either Charles or Mystic river. Our floats went up Charles river three times, Mystic once, and once stopped at the junction of the two rivers. The downward current, starting at high water, follows the main ship channel to the "narrows" between Long Island and Deer Island (three miles); thence through Broad Sound, carrying the floats in some instances to a point outside the "Graves" (eight miles). On the return of the flood, many of the floats were carried to the flats near Apple Island.

From STATION IV. (off Moon Head), the upward current, starting at low water, divides on the point of the head, one half going through Squantum Gut into Dorchester Bay (two miles and a half), and the other half into Quincy Bay (also two miles and a half). The downward current, starting at high water, generally carried the floats between Thompson's and Galloupe's Island and between

Lovell's and George's Island (about five miles). Some went south of George's Island towards Paddock's Island and Hull (three miles).

From STATION V. (off Commercial Point on Neponset river), the upward current, starting at low water, carries a float up the river as far as Granite bridge (two miles). The downward current, starting at high water, carries one north of Thompson's Island nearly or quite to Spectacle Island (three miles and a half).

From STATION VI. (opposite the Cow Pasture Buoy in Dorchester Bay) the downward current carried the floats generally as far as Spectacle Island (about two miles and a half), to be grounded on the flats of Apple Island, Thompson's Island, or Dorchester Bay by the next flood.

It is evident from inspection of our diagrams that the general shape of the courses of the tidal currents in Boston Harbor is somewhat like that of the sticks of an open fan; where Broad Sound or Boston Light would represent the handle or radiating point, and the sticks would be the various currents extending up towards Winthrop, Chelsea Beach, the main ship channel, Dorchester Bay, Quincy Bay, etc. The currents starting from all points along the shore appear to converge in the ebb toward Broad Sound, or Boston Light, and on the flood to diverge again toward some of the same points from which they started. But, of course, it is quite uncertain whether a float that starts down from Quincy Bay may not return up toward Winthrop, or *vice versa*.

In none of our experiments have I been able to obtain as long continued observations as I could have desired.

As to floats, it has been found impracticable to use those of the English Thames experiments (one-inch square sticks, fourteen feet long, floating vertically, nearly submerged) over our shallow flats, where, about the time of low tide, the water is only two or three feet deep. On the other hand, ten-inch tin cans, weighted; two-inch cubes of wood, weighted; bottles weighted with gravel, etc., — all proved insufficient to resist a wind, either against or with the current. Our best results were obtained either with two cans, one floating at the surface, and the other several feet below it, with a wooden cross or fan of four vertical blades (shingles) attached to the rope near the lower can; or with a float, consisting of four wooden arms, each five feet long, radiating from a centre, and floating on the surface of the water, with four vanes of stout cotton drilling, stretched on sticks let into the arms, and extending vertically two feet and a half down into the water below the arms; the whole weighted with a stone from the centre, so that the arms were almost submerged. One of the arms supported a slender stem with a small flag, and the arms are hinged at the centre, so that the whole shuts like a book when out of water, they being kept open when in use by a rope passed from one to the other, and knotted around the end of each.